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DEVELOPMENT OF A PAVEMENT MAINTENANCE MANAGEMENT SYSTEM

VOLUME I. AIRFIELD PAVEMENT CONDITION RATING

CONSTRUCTION ENGINEERING RESEARCH LABORATORY
CHAMPAIGN, ILLINOIS 61820

DECEMBER 1977

CEEDO

FINAL REPORT FOR PERIOD
JULY 1974-JULY 1976

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CIVIL AND ENVIRONMENTAL
ENGINEERING DEVELOPMENT OFFICE

(AIR FORCE SYSTEMS COMMAND)

TYNDALL AIR FORCE BASE
FLORIDA 32403

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This report describes the development and verification of a pavement condition index (PCI) for rating the condition of jointed concrete and asphalt- or tar-surfaced airfield pavements. The PCI, which measures airfield pavement structural integrity and surface operational condition, is calculated based on measured pavement distress types, severities, and densities obtained during an inspection of the pavement. Volume II of this report presents distress types, descriptions, severity levels, and measurement criteria for use in performing the pavement inspections.

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The PCI has been field tested and validated through the assistance of many airfield pavement engineers at nine airfields (over 100 pavements) located in widely different environments and subjected to different traffic conditions. Field tests indicated that the computed PCI compares well with the mean rating of experienced pavement engineers. The PCI was found to be much more consistent than the individual subjective ratings, since it is based on measured distress data. Preliminary guidelines for determining maintenance and repair needs based on the PCI are also presented.

PREFACE

This report documents work accomplished between July 1974 and July 1976 by the U S Army Construction Engineering Research Laboratory under MIPR No. FQ 89527666005 from the Air Force Civil Engineering Center (AFCEC), Tyndall AFB, Florida. Mr Donald N. Brown was Project Engineer for the Civil Engineering Center.

On 8 April 1977 AFCEC divided into two organizations. AFCEC became part of the Air Force Engineering and Services Agency (AFESA). The Research and Development function remains under Air Force Systems Command as Det 1 (Civil and Environmental Engineering Development Office (CEEDO)) HQ ADTC. Both units remain at Tyndall AFB FL 32403.

To assure continuity of publication of the remaining volumes of this work effort, it is necessary to supersede the published AFCEC Technical Report. CEEDO is the sponsoring agency and Mr Donald N. Brown remains as the Project Engineer.

This report has been reviewed by the Information Officer (OI) and is releasable to the National Technical Information Service (NTIS). At NTIS it will be available to the general public, including foreign nations.

This technical report has been reviewed and is approved for publication.

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Development

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SECTION I

INTRODUCTION

BACKGROUND

The Air Force has a very large inventory of old pavements that are rapidly approaching the end of their economic service lives. As a result, the maintenance required to keep these pavements in service is steadily increasing, and it is anticipated that this increase will become progressively greater with time. Therefore, the Air Force has identified the need for an adequate method of describing and/or determining the relative condition of airfield pavements; and for developing procedures for evaluating the consequence of using various maintenance strategies to extend the service life of existing pavements. In addition, improved methods are needed for assignment of maintenance priorities to assure optimum use of available maintenance funds.[1]

Assuring efficient and economical use of maintenance funds requires a pavement maintenance management system. The U.S. Army Construction Engineering Research Laboratory (CERL) is developing such a system under contract with Air Force Civil Engineering Center (AFCEC). The complete pavement maintenance management system is expected to include:

1. Improved and field-validated condition survey procedures for jointed concrete and asphalt- or tar-surfaced airfield pavements.

2. Objective methods for determining pavement condition indices based on data obtained from pavement condition surveys.

3. A revised version of Air Force Regulation (AFR) 93-5,[2] Chapter 3, entitled "Airfield Pavement Condition Survey Report."

4. Methods for evaluating the consequences of using various maintenance strategies; the methods will provide procedures for selecting the best specific maintenance strategies based on pavement condition.

5. Methods for assigning maintenance priorities which will assure efficient and economic use of available maintenance funds.

6. A computer package consisting of a data bank and computation system based on all the developments resulting from work described in 1 through 5. The computer package will provide an up-to-date pavement

[1] "Statement of Work," Military Interdepartmental Purchase Request No. FQ89527666005 (U.S. Air Force Civil Engineering Center [AFCEC] 11 August 1975).

[2] *Airfield Pavement Evaluation Program*, AFR 93-5 (Department of the Air Force, 17 July 1974).

maintenance management system and will be easily adapted to any existing computer used by the Air Force.

7. Field demonstration of the final version of the pavement maintenance management system at one Air Force base will be required.

OBJECTIVE

The objective of this study is to develop a pavement condition index for rating airfield pavement condition. Some of the specific objectives of the pavement condition rating procedure are:

1. To indicate the present condition of the pavement in terms of structural integrity and operational surface condition.

2. To provide the base civil engineer with an objective and rational basis for determining maintenance and repair needs and priorities, and with a warning system for early identification and/or projection of major repair requirements.

3. To provide the major commands with a common index for use in comparing the condition and performance of pavements at all operational bases within their jurisdictions and in determining justification for major repair projects, and to provide a basis for in-depth pavement evaluation by the AFCEC.

4. To provide Headquarters, U.S. Air Force (HQ, USAF) with a rational basis for assigning priorities for in-depth pavement evaluations by AFCEC specialty teams.

5. To provide feedback on pavement performance for validation or improvement of current pavement design procedures and maintenance practices.

APPROACH

This report presents the results of work performed during fiscal years 1975-76. The work primarily consisted of developing airfield pavement condition survey and rating methods. These methods were field tested, revised, and validated at nine airfields located in different climates and subjected to varying traffic. Figure 1 shows the names and locations of the airfields surveyed.

Figure 2 summarizes the condition rating procedure and indicates the six steps necessary to determine an airfield feature pavement condition rating. These six steps are described briefly below.

1. The pavement feature is inspected, and distress types and their severity levels and density are recorded. Volume II of this report, entitled *Airfield Pavement Distress Identification Manual*, provides a reference for performing the condition survey. It is imperative that

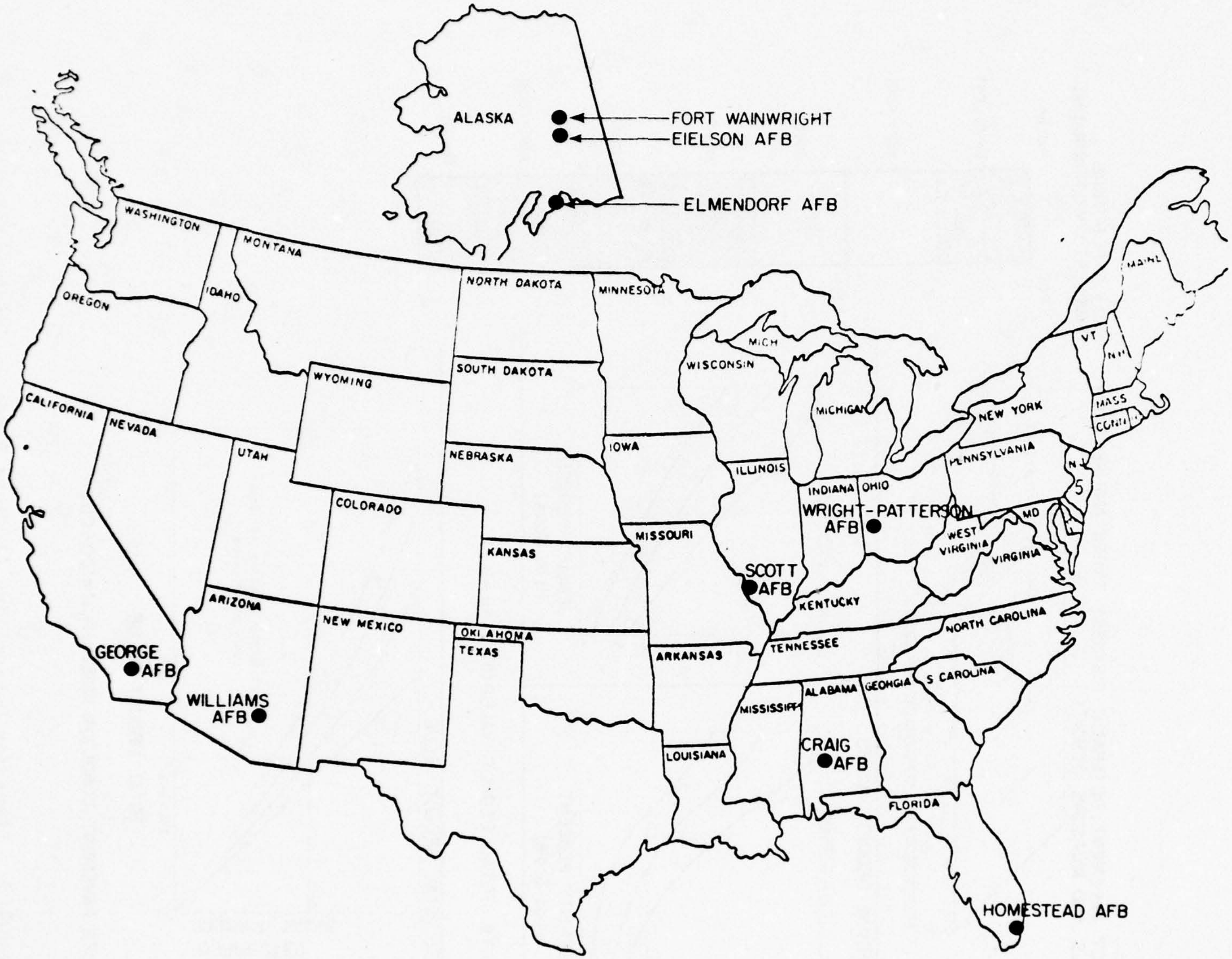

Figure 1. Airfields Surveyed for Testing and Validation of the Pavement Condition Index.

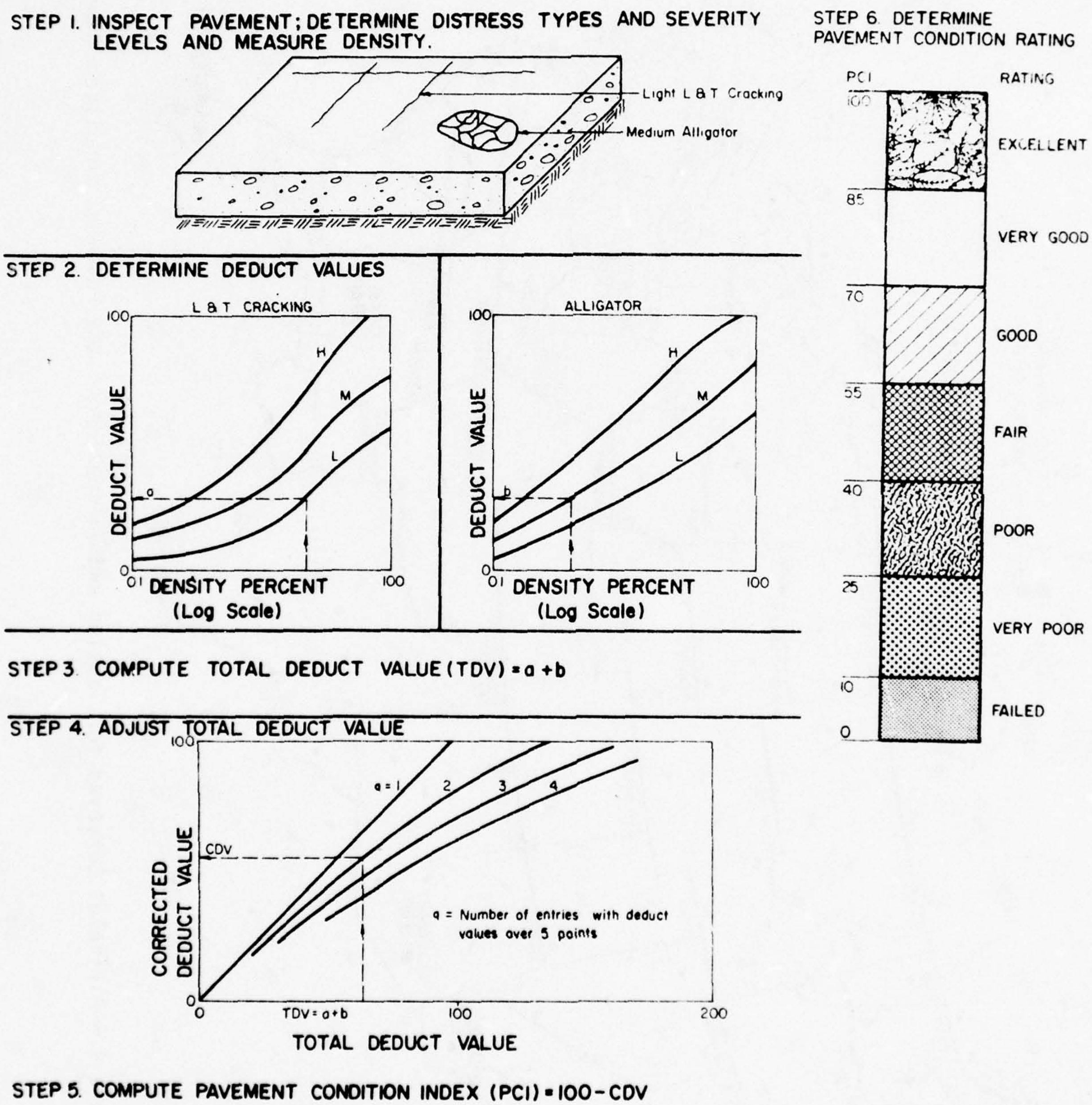

Figure 2. Steps for Determining Airfield Pavement Condition Rating.

criteria in the manual be used in identifying and recording the distress types.

2. For each distress type, density, and severity level, a deduct value is determined from the appropriate curve.

3. The total deduct value (TDV) is determined by adding all deduct values from each distress condition observed.

4. A corrected deduct value (CDV) is determined based on the TDV and the number of distress conditions observed with individual deduct values over five points (two such conditions were observed in the example shown in Figure 2).

5. The pavement condition index (PCI) is calculated as follows:

$$PCI = 100 - CDV$$

6. The pavement condition rating is determined from Figure 2, which presents narrative terms describing pavement condition as a function of PCI value.

A preliminary revision of Chapter 3 of AFR 93-5 containing detailed procedures was prepared (Appendix A). Preliminary guidelines for determining maintenance and repair needs of pavements as a function of the PCI were also developed.

ORGANIZATION OF REPORT

Section II describes current procedures which are available for determining airfield pavement condition based on measured observable pavement distresses. Section III provides information about the types and frequency of occurrence of distresses found on jointed concrete and asphalt- or tar-surfaced airfield pavements.

Section IV describes the concepts and theory used in developing the PCI. These concepts and theory are implemented for jointed concrete pavements in Section V and asphalt- or tar-surfaced pavements in Section VI.

Section VII presents guidelines for inspecting pavements and a procedure for sampling when time does not permit inspection of the entire pavement area. Section VIII presents the guidelines for determining maintenance and repair needs based on the PCI.

Section IX summarizes the work and presents the conclusions and recommendations.

Complete guidelines prepared for use by the pavement inspector in rating the condition of airfield pavement are contained in Appendix A.

SECTION II

CURRENT AIRFIELD PAVEMENT CONDITION SURVEY PROCEDURES

Two procedures are currently available for determining airfield pavement condition based on measured observable pavement distresses; one of these procedures is being used by the Air Force and another by the Navy and Marine Corps. This section summarizes these two procedures and evaluates their capability to measure pavement condition.

CURRENT AIR FORCE CONDITION SURVEY PROCEDURE

Air Force airfield pavement condition surveys are currently being performed by major command civil engineers at all operational bases within each command jurisdiction on a 5-year recurring cycle. The survey is principally a visual examination of pavement facilities to observe their reactions to imposed aircraft loadings and to determine their operational conditions. In addition to establishing the pavement condition, the results of the survey are used as supporting documents for programming airfield maintenance and repair projects and establishing the need for in-depth pavement evaluation by the AFCEC.

The airfield pavement network at each Air Force base is first divided into features having the same design and construction history. The features are outlined and identified on the airfield layout plan (Figure 3), and surveyed, as described below.

Jointed Concrete Pavement (Rigid Pavement) Condition Survey

Each concrete pavement feature is divided into lanes (single rows of slabs); the slabs comprising each pair of lanes are numbered in ascending order in the direction of the survey's progression. This drawing is then used as the condition survey format (Figure 4). To facilitate recording of distresses on the condition survey format, each distress is given a symbol, as shown in Figure 5. The inspector performs the survey by walking along the feature and recording the distress in each slab, as shown in Figure 6. When the survey has been completed, the results are tabulated on a summary form, as shown in Figure 7. The "percentage of slabs no defects" appearing on the summary form is computed by subtracting the percentage of slabs containing defects from 100. The "percentage slabs no major defects"[3] is calculated similarly.

The pavement's condition is classified according to five condition categories--excellent, very good, good, fair, and poor--based on the percentage of slabs having no major defects, the percentage of slabs

[3]For purposes of this computation, major defects are defined as those that will impair a pavement's load-carrying capacity, including longitudinal cracks, transverse cracks, diagonal cracks, corner breaks, and shattered slabs.

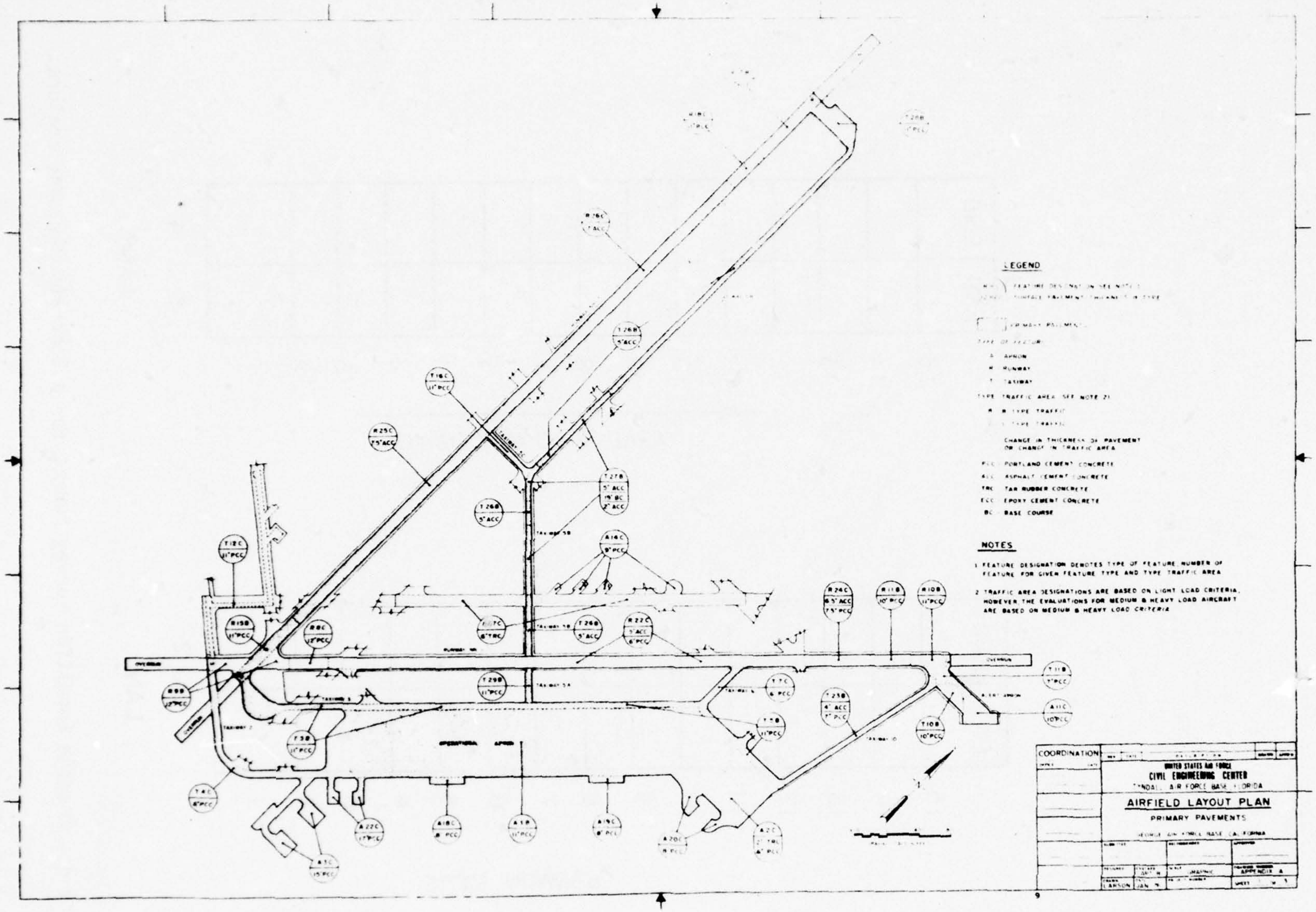

Figure 3. Pavement Features Identified on Airfield Layout Plan.

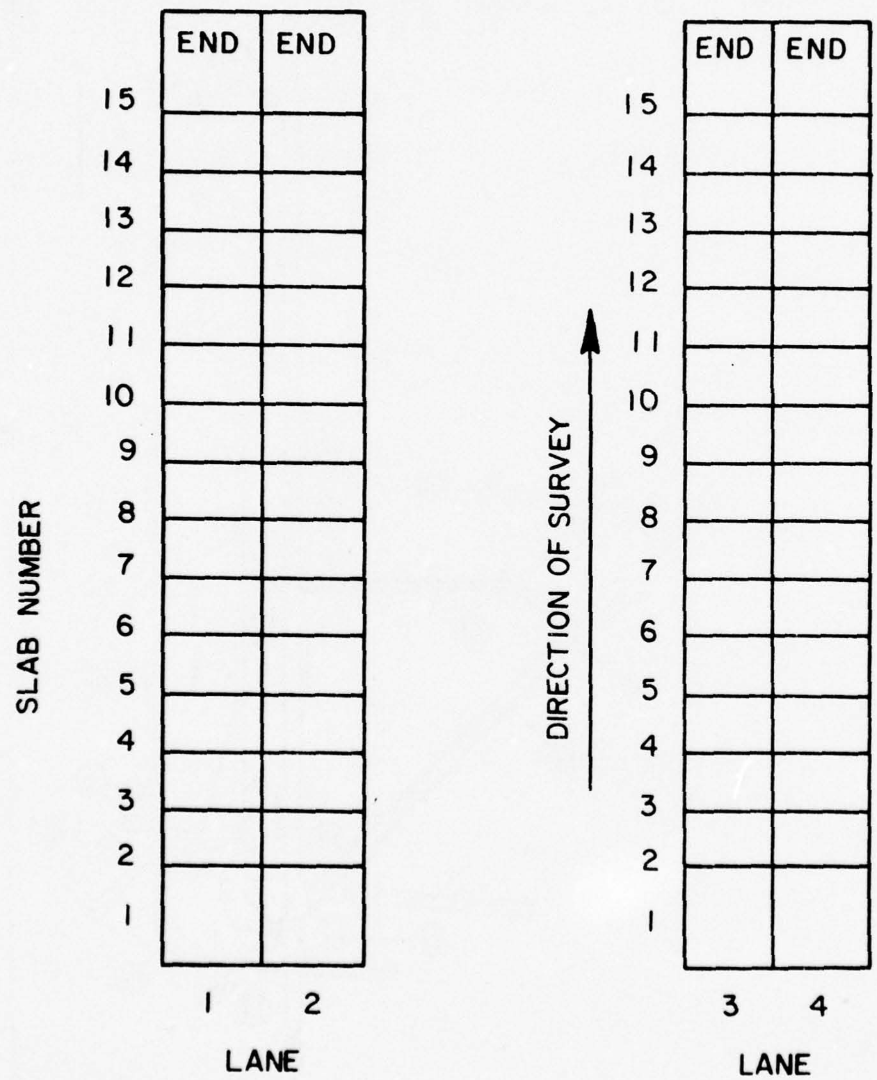

Figure 4. Example Condition Survey Format for a Concrete Pavement Feature.

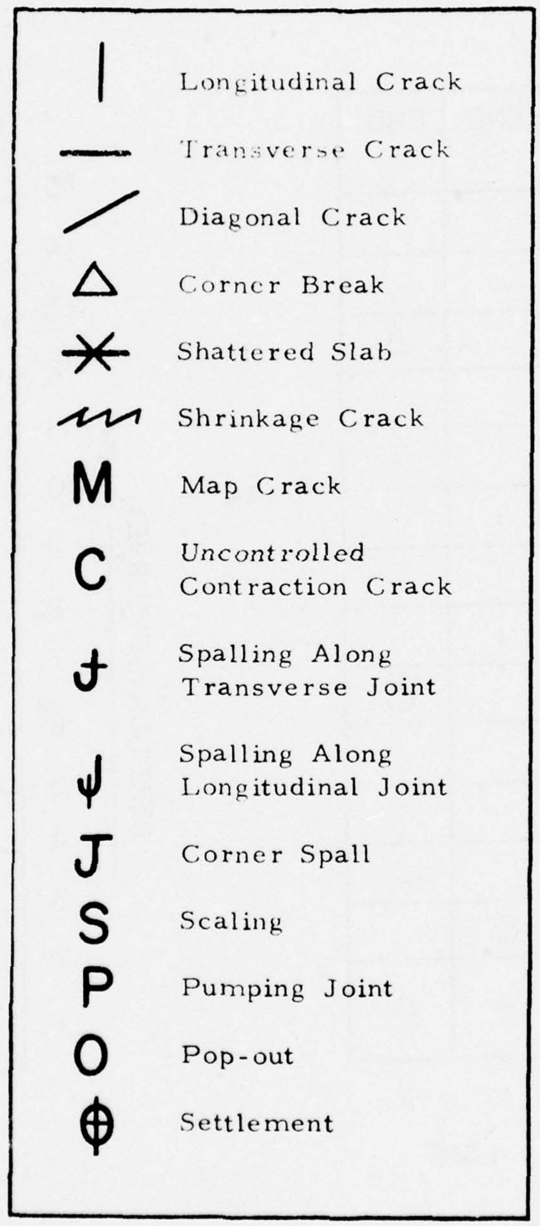

Figure 5. Signs and Symbols for Recording Concrete Pavement Distress. From *Airfield Pavement Evaluation Program*, AFR 93-5 (Department of the Air Force, 17 July 1974).

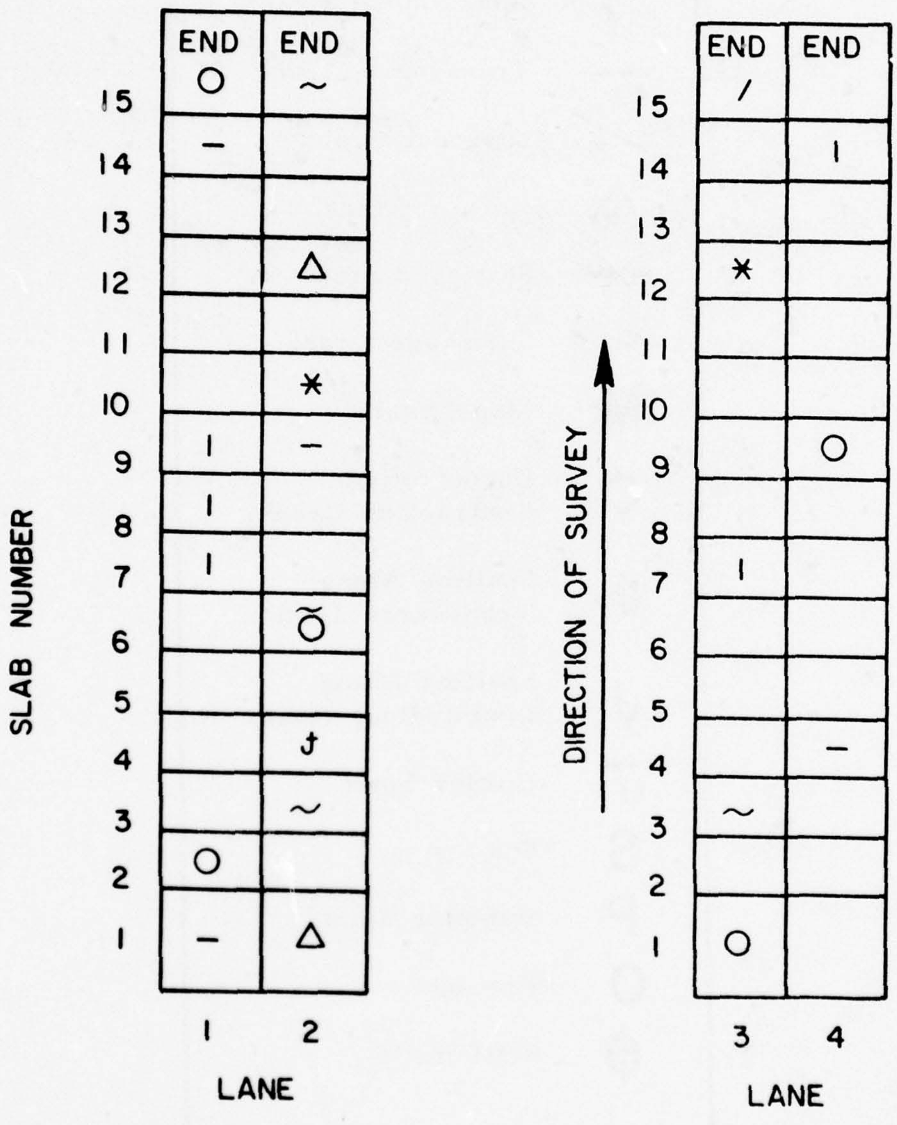

Figure 6. Example Condition Survey Format Showing Distresses in Concrete Pavement Feature.

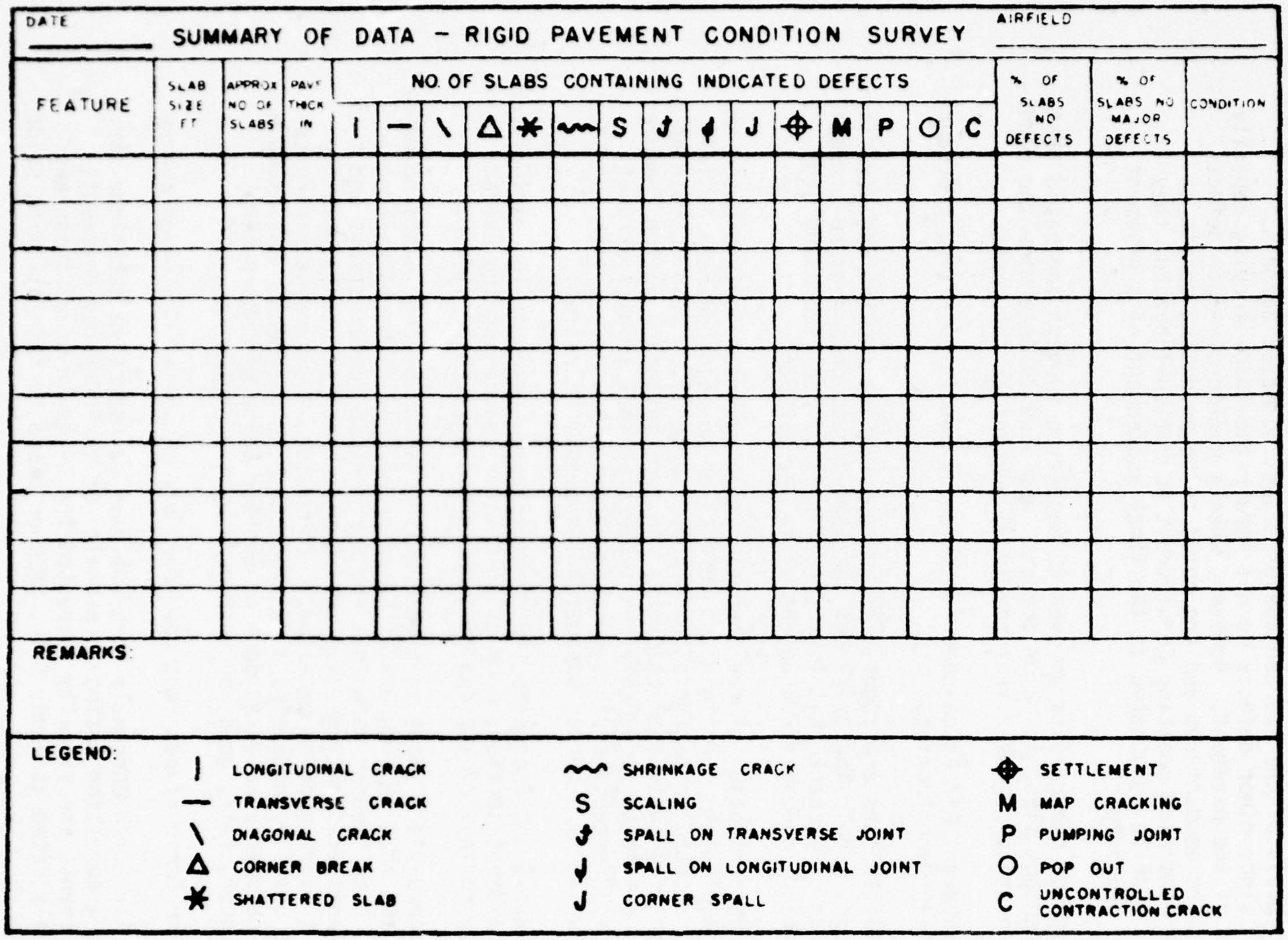

Figure 7. Summary of Data - Concrete Pavement Condition Survey. From *Airfield Pavement Evaluation Program*, AFR 93-5 (Department of the Air Force, 17 July 1974).

having no defects, and engineering judgment. Table 1 is a general guideline used to establish concrete pavement condition. Regarding use of this table to establish pavement condition, AFR 93-5 recommends the following:

> "The condition of a rigid pavement is usually assigned on the basis of the 'percentage of slabs, no major defects,' since minor defects do not impair the load-carrying capacity of the pavement. However, when a number of minor defects are encountered and are noted to be producing debris or otherwise creating an aircraft operational hazard, they must be considered in the final assignment of a pavement condition."

Examination of the results of over 20 condition surveys indicated that the "percentage slabs no major defects" was used to determine the condition of concrete pavement features in 95 percent of the cases.

The current Air Force concrete pavement condition rating procedure has two major shortcomings:

1. Distresses are identified by type without considering severity. For example, a hairline crack has the same impact on a feature's condition rating as a crack that is severely spalled and is causing high foreign object damage (FOD) potential to jet aircraft.

2. Determination of the condition of a pavement feature based on percentage of slabs containing no defects or no major defects is inadequate. According to these guidelines (Table 1), a slab containing a transverse or longitudinal crack has the same influence on the feature's condition rating as a severely shattered slab that impairs aircraft operations. Percentage slabs containing a certain defect with specific severity would be a better parameter for condition rating.

Figures 8 and 9 compare the concrete pavement condition ratings for several pavement sections made using this procedure and the average subjective ratings of a group of experienced pavement engineers.

The comparison shown in Figure 8 is based on percent slabs no major defects, and that in Figure 9 is based on percent slabs containing no defects. Both figures show that the current Air Force ratings and average engineers' ratings have reasonable correlation only when the pavement is very good or excellent. Otherwise, the current Air Force procedure usually underrates a jointed concrete pavement. For example, concrete pavements rated as poor by the Air Force procedure were rated as poor, fair, good, or very good by the engineers.

Asphalt- or Tar-Surfaced Pavement (Flexible Pavement) Condition Survey

The Air Force currently does not have an objective technique for assigning a condition rating to asphalt- or tar-surfaced pavements. These pavements are visually inspected for evidence of distress and subjectively rated as good, fair, or poor based on the following guidelines:

TABLE 1. GENERAL GUIDELINE FOR ESTABLISHING CONCRETE PAVEMENT CONDITION[a]

Percentage Slabs No Defects		Percentage Slabs No Major Defects		Condition
k=25 to 200	k > 200	k=25 to 200	k > 200	
90 - 100	90 - 100	98 - 100	90 - 100	Excellent
80 - 90	80 - 90	90 - 98	80 - 90	Very Good
70 - 80	60 - 80	80 - 90	70 - 80	Good
60 - 70	50 - 60	70 - 80	60 - 70	Fair
<60	<50	<70	<60	Poor

[a]From *Airfield Pavement Evaluation Program*, AFR 93-5 (Department of the Air Force, 17 July 1974).

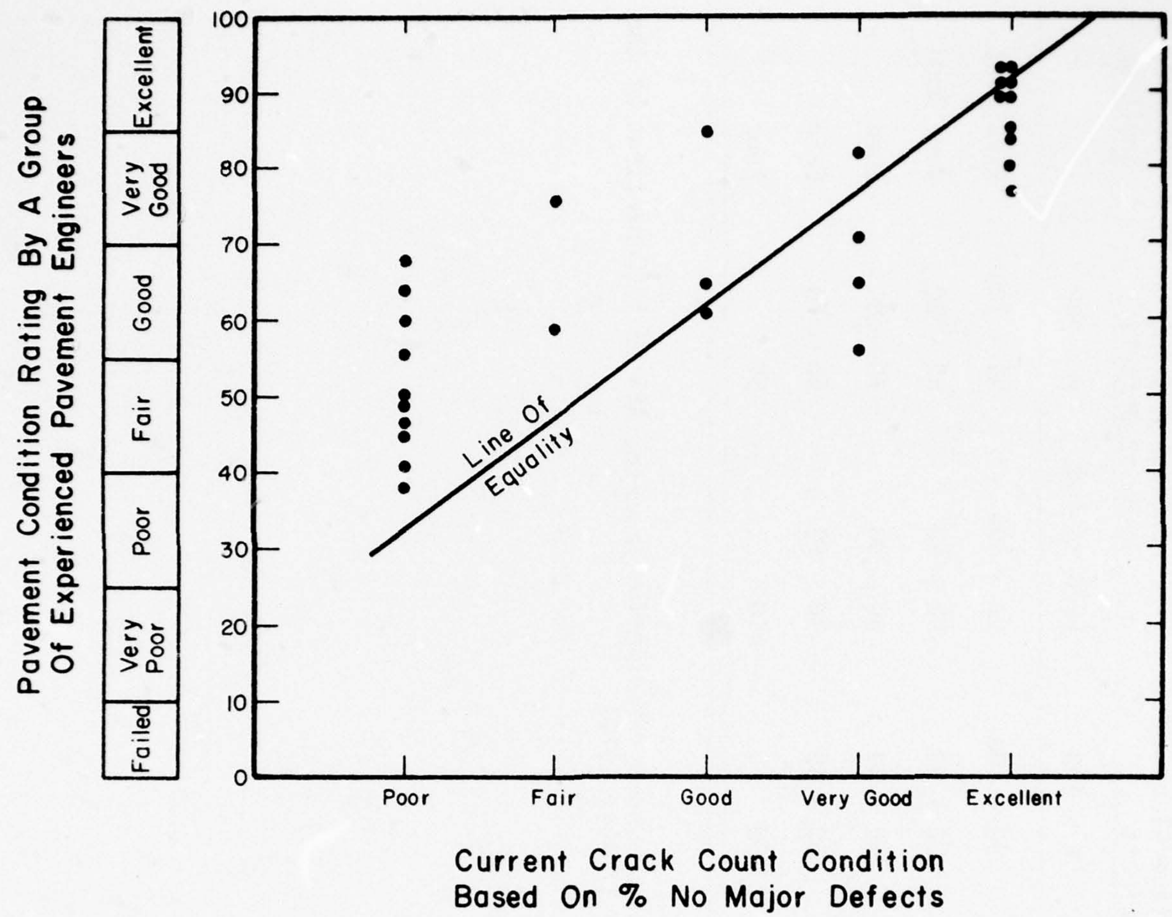

Figure 8. Pavement Condition Rating Using Current Air Force Procedure (Percent Slabs No Major Defects) vs Pavement Condition Rating by a Group of Experienced Pavement Engineers.

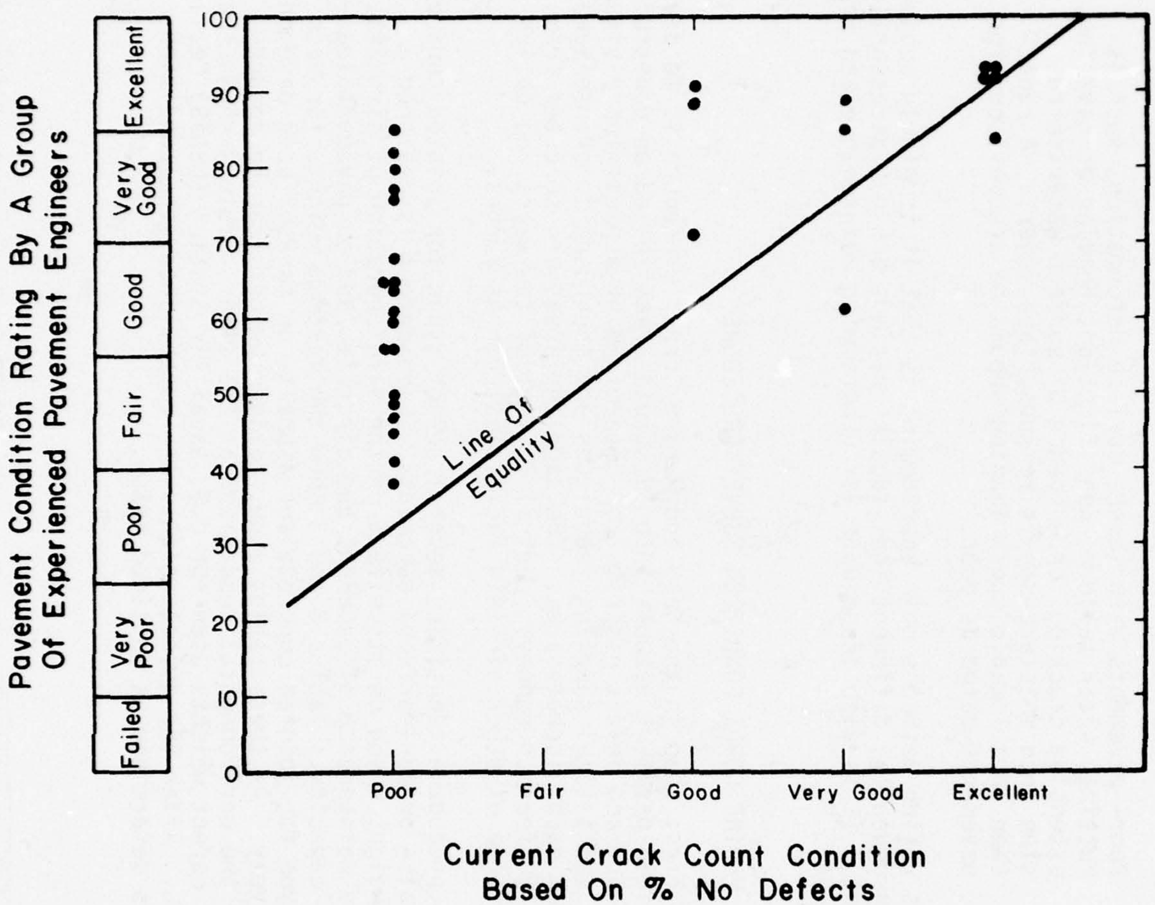

Figure 9. Pavement Condition Rating Using Current Air Force Procedure (Percent Slabs No Major Defects) vs Pavement Condition Rating by a Group of Experienced Pavement Engineers.

1. Good--pavements in better than average condition with no conspicuous evidence of deformation or incipient failures and with few (if any) longitudinal, transverse, or shrinkage cracks. All existing defects are being properly maintained.

2. Fair--pavements with a higher percentage of transverse, longitudinal, or pattern cracking and minor defects, such as weathered or oxidized surface, random cracking, and minor deformation or rutting.

3. Poor--pavements with severe surface deformation, such as rutting, shear failure, densification, heaving or raveling, extensive cracking, or evidence of surface water intrusion into moisture-sensitive subsurface layers. A reduction in allowable gross loading should be accomplished for pavements rated as poor.[4]

This rating method's main shortcoming is that it is highly subjective; consequently, different individuals' ratings are not necessarily consistent. It is also inadequate for programming maintenance and repair requirements.

NAVY AND MARINE CORPS CONDITION SURVEY PROCEDURE

The first step in the Navy and Marine Corps[5] procedure is to divide the airfield pavement network into "discrete areas" based on construction history and defect distribution determined by a preliminary visual survey. Statistical sampling techniques are then used to choose sample areas from each discrete area. The sampling areas are selected from the central 100 feet of runways, central 50 feet of taxiways, and entire discrete area of other airfield facilities such as aprons.

The procedure identifies several defect types for jointed concrete and asphalt- or tar-surfaced pavements. Each defect is assigned a maximum weight based on its effect on the safe operation of aircraft, on increased maintenance of pavement and aircraft, and on pavement load-carrying capacity. Tables 2 and 3 show the maximum weights for each defect type for jointed concrete and asphalt- or tar-surfaced pavements, respectively. As these tables show, maximum weights can be reduced based on the environmental conditions at the site. Table 4 shows the specific defect weights used for U.S. Naval Air Station (USNAS) Cecil Field, FL. After the defect weights are established, the condition rating is determined as outlined below.

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[4] *Airfield Pavement Evaluation Program*, AFR 93-5 (Department of the Air Force, 17 July 1974).

[5] *Field Procedures and Techniques for Conducting Naval and Marine Corps Airfield Pavement Condition Surveys*, DM-21 (Naval Civil Engineering Laboratory, October 1972).

TABLE 2. SEVERITY WEIGHTS FOR DEFECTS IN CONCRETE AIRFIELD PAVEMENTS USED BY THE NAVY[a]

QUESTIONS

1 (Yes = 3.0) Does the defect affect the safe operation of aircraft now?
2 (Yes = 1.5) Will the defect lead to increased airfield maintenance effort within 1 to 2 years?
3 (Yes = 1.5) Will the defect lead to increased aircraft operational costs within 1 to 2 years?
4 (Yes = 1.5) Will the defect result in significant deterioration of load carrying capacity within 5 years?
5 (Yes = 1.5) Will the defect lead to unsafe aircraft operations within 5 years?

Portland Cement Concrete Pavement

Defect Type	Method of Measurement	Answers to Questions					Total (Highest Possible Weight)	Environmental Modifiers If No...			
		1	2	3	4	5		Cold Weather	Heavy Rainfall	Poor-draining Subgrade	Blow Sand
Faulting		Yes 3.0	Yes 1.5	Yes 1.5	Yes 1.5	Yes 1.5	9.0	-0.5			
Depression		Yes 3.0	Yes 1.5	Yes 1.5	Yes 1.5	Yes 1.5	9.0				
Shattered Slab		Yes 3.0	Yes 1.5	Yes 1.5	Yes 1.5	Yes 1.5	9.0				
Spall		Yes 3.0	Yes 1.5	Yes 1.5	No -	Yes 1.5	7.5				
Scaling		Yes 3.0	Yes 1.5	Yes 1.5	No -	Yes 1.5	7.5	-0.5			
"D" Line Cracking		Yes 3.0	Yes 1.5	Yes 1.5	No -	Yes 1.5	7.5	-0.5			-0.5
Joint Seal Prob.		No -	Yes 1.5	No -	Yes 1.5	Yes 1.5	4.5	-0.5	-0.5	-0.5	-0.5
Pumping		No -	Yes 1.5	No -	Yes 1.5	Yes 1.5	4.5		-0.5	-0.5	
Corner Break		No -	Yes 1.5	No -	Yes 1.5	Yes 1.5	4.5	-0.5	-0.5	-0.5	-0.5
Inter-secting Crack		No -	Yes 1.5	No -	Yes 1.5	Yes 1.5	4.5	-0.5	-0.5	-05	-0.5
L.C. or T.C.		No -	Yes 1.5	No -	No -	Yes 1.5					

Longitudinal Crack: T.C. = Transverse Crack; L.C.J.C. = Longitudinal Construction Crack

[a] *Field Procedures and Techniques for Conducting Naval and Marine Corps Airfield Pavement Condition Surveys*, DM-21 (Naval Civil Engineering Laboratory, October 1972).

TABLE 3. SEVERITY WEIGHTS FOR DEFECTS IN ASPHALT- AND TAR-SURFACED AIRFIELD PAVEMENTS USED BY THE NAVY[a]

QUESTIONS

1 (Yes = 3.0) Does the defect affect the safe operation of aircraft now?
2 (Yes = 1.5) Will the defect lead to increased airfield maintenance effort within 1 to 2 years?
3 (Yes = 1.5) Will the defect lead to increased aircraft operational costs within 1 to 2 years?
4 (Yes = 1.5) Will the defect result in significant deterioration of load carrying capacity within 5 years?
5 (Yes = 1.5) Will the defect lead to unsafe aircraft operations within 5 years?

Asphaltic Concrete Pavement

Defect Type	Method of Measurement	Answers to Questions 1	2	3	4	5	Total Highest Possible Weight	Environmental Modifiers: Cold Weather	Heavy Rain-fall	Poor Drainage	Blow Sand
Faulting	Lin. ft.	Yes 3.0	Yes 1.5	Yes 1.5	Yes 1.5	Yes 1.5	9.0	-0.5			
Depression	ft.^{2}	Yes 3.0	Yes 1.5	Yes 1.5	Yes 1.5	Yes 1.5	9.0				
Rutting	ft.^{2}	Yes 3.0	Yes 1.5	Yes 1.5	Yes 1.5	Yes 1.5	9.0				
Broken-up Area	ft.^{2}	Yes 3.0	Yes 1.5	Yes 1.5	Yes 1.5	Yes 1.5	9.0				
Raveling	ft.^{2}	Yes 3.0	Yes 1.5	Yes 1.5	No -	Yes 1.5	7.5	-0.5			
Erosion-Jet Blast	ft.^{2}	Yes 3.0	Yes 1.5	Yes 1.5	No -	Yes 1.5	7.5				
L.C., T.C., or L.C.J.C.	Lin. ft.	No -	Yes 1.5	No -	Yes 1.5	Yes 1.5	4.5	-0.5	-0.5	-0.5	-0.5
Pattern Cracking	ft.^{2}	No -	Yes 1.5	No -	Yes 1.5	Yes 1.5	4.5	-0.5	-0.5	-0.5	-0.5
Patching	ft.^{2}	No -	Yes 1.5	No -	Yes 1.5	Yes 1.5	4.5	-0.5	-0.5	-0.5	
Reflection Crack	Lin. ft.	No -	Yes 1.5	No -	No -	Yes 1.5	3.0	-0.5	-0.5	-0.5	-0.5

[a]*Field Procedures and Techniques for Conducting Naval and Marine Corps Airfield Pavement Condition Surveys*, DM-21 (Naval Civil Engineering Laboratory, October 1972).

TABLE 4. DEFECT SEVERITY WEIGHTS USED FOR AIRFIELD AT USNAS CECIL FIELD, FL[a]

Asphaltic Concrete		Portland Cement Concrete	
Defect	Weight	Defect	Weight
Depression.	9.0	Depression.	9.0
Rutting	9.0	Shattered Slab.	9.0
Broken-up Area.	9.0	Faulting.	8.5
Faulting.	8.5	Spalling.	7.5
Raveling.	7.0	Scaling.	7.0
Erosion-Jet Blast.	7.5	"D-Line" Cracking.	6.5
Longitudinal, Transverse, or Longitudinal Construction Joint Crack	3.0	Pumping.	4.0
		Poor Joint Seal.	3.0
Pattern Cracking	3.0	Corner Break	3.0
Patching	3.5	Intersecting Crack	3.0
Reflection Crack	1.5	Longitudinal or Transverse Crack.	1.5
Oil Spillage.	1.5		

[a]From D. J. Lambiotte and R. B. Brownie, *Airfield Pavement Condition Survey, USNAS, Cecil Field, Florida*, Technical Note N-1155 (Naval Civil Engineering Laboratory, March 1971).

Jointed Concrete Pavements

Each slab in a sampling area is considered a unit and is counted as defective if a distress type occurs once or more within the slab. If more than one distress type is found on a given slab, the slab is tallied once for each distress type. Once the defect tally has been made, defect densities are calculated (defect density is defined as the ratio of slabs containing the defect to the total number of slabs in the sample area). The sum of each defect density times defect severity weight gives the "weighted defect density," which is the final score for the discrete area. The higher the score, the worse the pavement condition is. Table 5 shows an example calculation of the "weighted defect density" for a runway discrete area.

Asphalt- or Tar-Surfaced Pavements

Sample areas (50 x 50 feet each) are first located in the "discrete area" to be rated. The amount of each distress present is measured in the units of measurement shown in Table 3. The defect density is then calculated as the amount of the distress per 10 square feet proportioned to the entire discrete area. The weighted defect density is obtained by multiplying the defect density by the defect severity weight. The higher the total weighted defect density, the worse the pavement condition is. Table 6 shows an example calculation of the weighted defect density for a taxiway discrete area.

Discussion of the Navy and Marine Corps Procedure

The sampling techniques used in the procedure make the condition survey less tedious than surveying the entire section without losing much accuracy. However, the procedure has several shortcomings:

1. Severity levels for each defect type are not considered. For example, the final rating does not differentiate between a 1/4-inch-deep rut and 2-inch-deep rut.

2. The list of defect types is not comprehensive. For example, there is no place to record patching in jointed concrete pavements, a distress which is common in nearly all airfields. In asphalt- or tar-surfaced pavements, block (temperature-associated) and fatigue (load-associated) cracking are combined as pattern cracking. This combination is inadequate from a condition rating, maintenance, and repair programming standpoint.

3. The relative severity weighting system is inadequate. For example, pattern cracking is given the same severity weight as longitudinal and transverse cracking (Table 3). Since fatigue cracking (which is included in pattern cracking) is a major structural distress, it should be given a much higher severity weight than linear cracking.

Figures 10 and 11 compare the Navy procedure ratings and the average rating by a group of experienced pavement engineers for jointed concrete and asphalt- or tar-surfaced pavements, respectively. The

TABLE 5. PORTLAND CEMENT CONCRETE DISCRETE AREA DEFECT SUMMARY[a]

Airfield USNAS Cecil Field Facility Runway 18L-36R

Discrete Area R18L-3 Total Slabs in Discrete Area (a) 2,400

No. of Slabs Sampled (b) 200 Ratio a/b = 12.0

Defect Type	No. of Sample Slabs w/Defect	Total Slabs w/defect c x a/b	Defect Density (per slab) d/a	Defect Severity Weight	Weighted Defect Density e x f
	(c)	(d)	(e)	(f)	(g)
Faulting					
Corner Break					
L.C. or T.C.[b]					
I.C.[c]					
Depression					
Spalling	16	192	0.080	7.5	0.60
Scaling					
Shattered Slab					
Joint Seal	50	600	0.250	3.0	0.75
Pumping					
"D-line" cracking					

Remarks on Pavement Condition Total 1.35C[d]

The joint seal was hard and had bond failures in the end 1000 feet of runway. The evaluators were unable to determine if a different type of seal was used in this area. The remainder of the joint seal was generally acceptable.

Most spalls were small, less than 1 inch wide and 6 inches long. A few spalls were up to 6 inches wide and 2 feet long.

[a]From D. J. Lambiotte and R. B. Brownie, *Airfield Pavement Condition Survey, USNAS, Cecil Field, Florida*, Technical Note N-1155 (Naval Civil Engineering Laboratory, March 1971).

[b]Longitudinal crack or transverse crack

[c]Intersecting crack

[d]Letter suffix "C" represents PCC pavement

TABLE 6. ASPHALTIC CONCRETE DISCRETE AREA DEFECT SUMMARY[a]

Airfield USNAS Cecil Field — Facility Taxiway C

Discrete Area TC-3 — Area of Discrete Area (a) 43,250 ft^2

No. of Sample Area (b) 4[b] — Ratio: (a/2500b) 4.3

Defect Type	Length of Area of Sampled Defects	Total Length of Area of All Defects: (c) x Ratio	Defect Density (per 10 sq ft) 10 d/a	Defect Severity Weight	Weighted Defect Density (e) x (f)
	(c)	(d)	(e)	(f)	(g)
T.C., L.C. or LCJ[c]	825 ft	3,548 ft	0.820	3.0	2.46
Reflection Crack					
Faulting					
Patching					
Settlement or Depression					
Pattern Cracking	2,100 ft^2	9,030 ft^2	2.088	3.0	6.26
Rutting					
Raveling					
Erosion--Jet Blast					
Oil Spillage					
Broken-up Area					
			Total		8.72A[d]

Remarks on Pavement Condition

This section on taxiway is seldom used. The pattern cracking was probably caused by shrinkage. The cracks were generally 1/16 inch or less in width and were unsealed. The longitudinal construction joint cracks were open to a width of 1/4 inch.

[a] From D. J. Lambiotte and R. B. Brownie, *Airfield Pavement Condition Survey, USNAS, Cecil Field, Florida*, Technical Note N-1155 (Naval Civil Engineering Laboratory, March 1971).

[b] Each sample area is 50 ft x 50 ft (2500 sq ft).

[c] Transverse crack, longitudinal crack or longitudinal construction joint crack.

[d] Letter suffix "A" indicates asphaltic pavement.

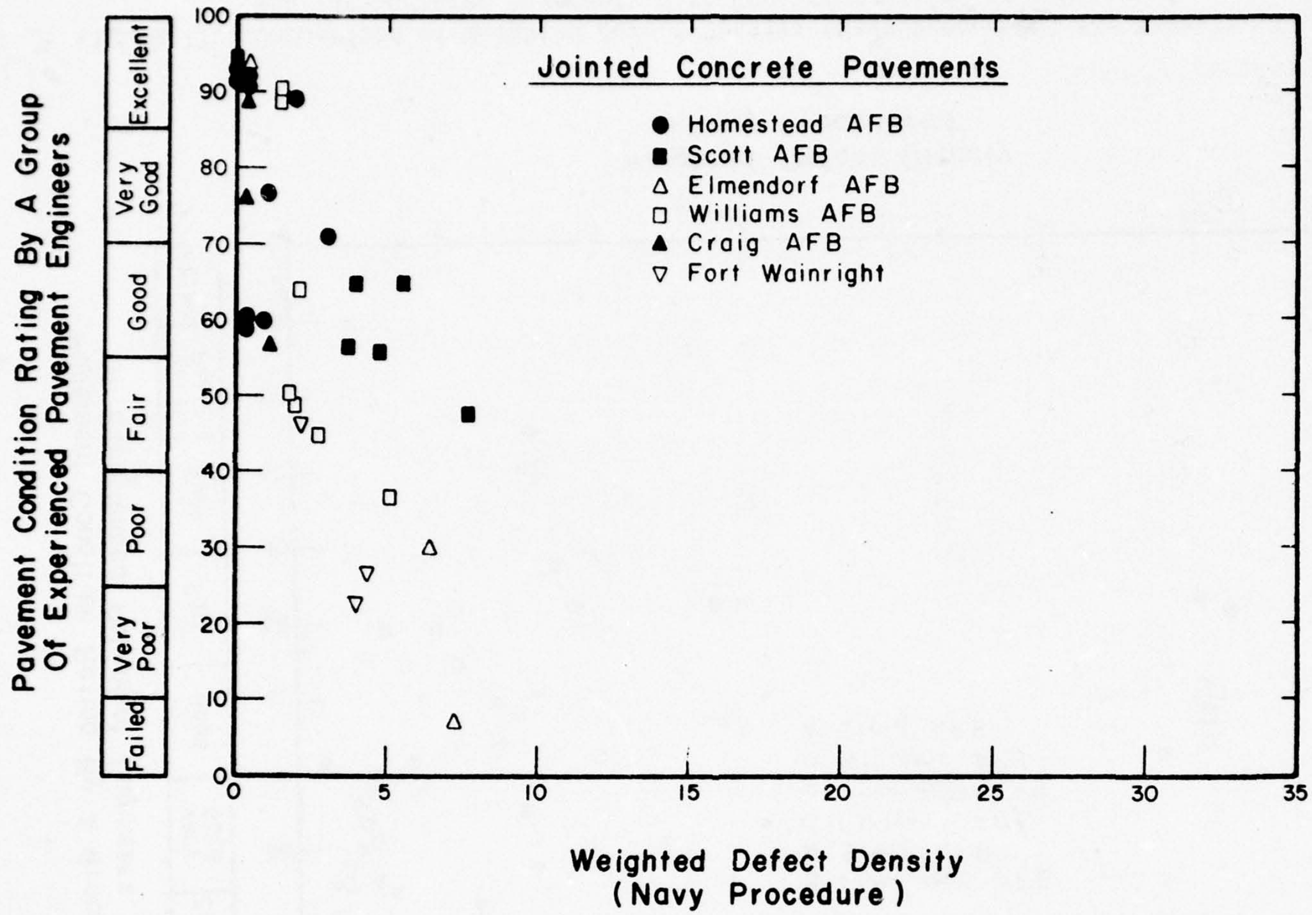

Figure 10. Comparison of Weighted Defect Density (Navy Procedure) For Jointed Concrete Pavements With Condition Rating by a Group of Experienced Pavement Engineers.

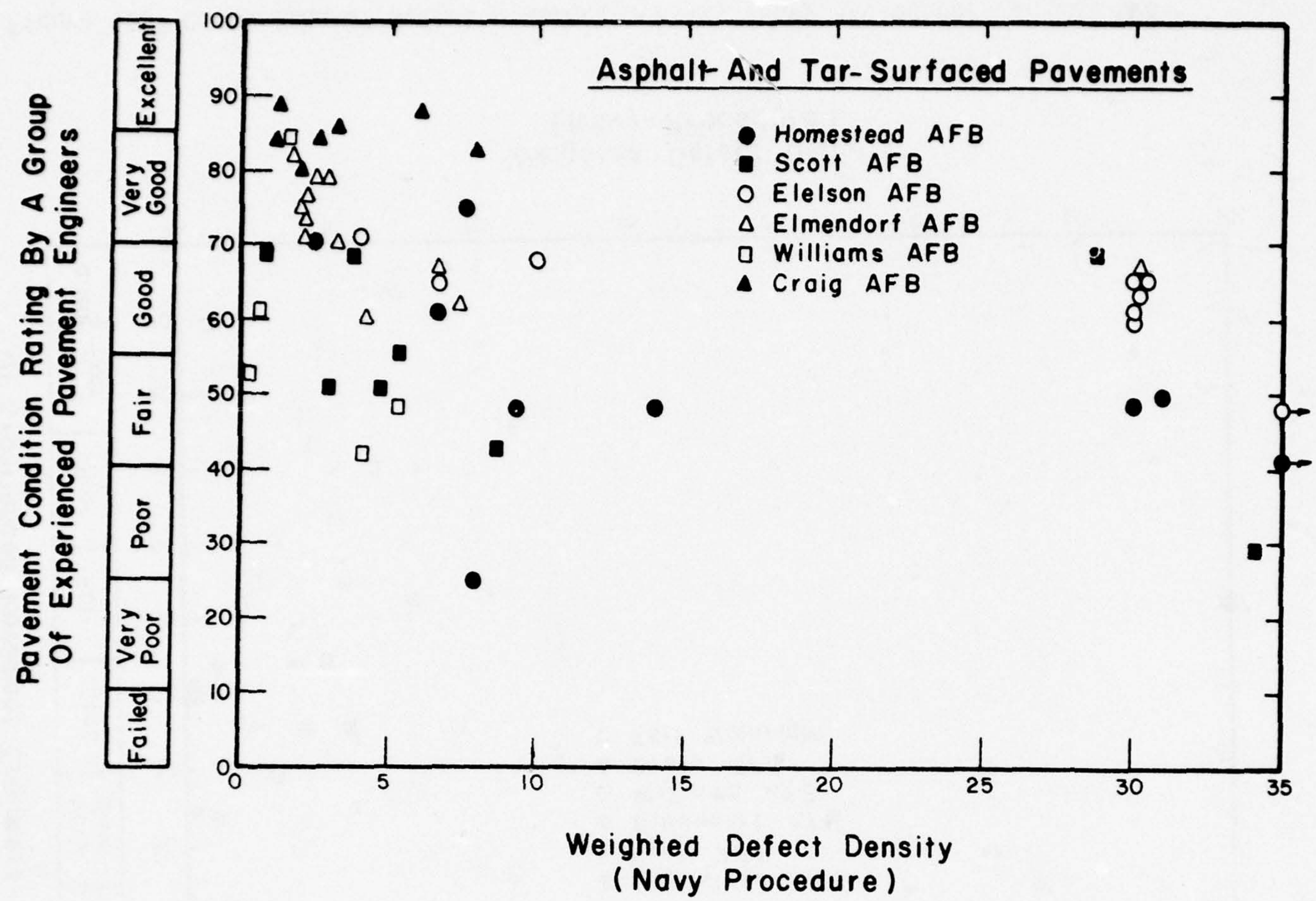

Figure 11. Comparison of Weighted Defect Density (Navy Procedure) for Asphalt- and Tar-Surfaced Pavements With Condition Rating by a Group of Experienced Pavement Engineers.

figures show that as the weighted defect density increases, the pavement condition rating generally decreases. However, the correlation between the Navy score (weighted defect density) and the mean pavement condition rating of the pavement engineers is poor. For example, pavement engineers ratings of jointed concrete pavements with a weighted defect density of 4 ranged from poor to very good, as shown in Figure 10. Similarly, an asphalt- or tar-surfaced pavement with a score of 4 was rated between poor and excellent by the engineers, as shown in Figure 11.

Figure 11 shows that several asphalt- or tar-surfaced pavements had very high weighted defect densities and no correlation with the actual pavement defects at 100 percent density. For example, the defect density according to the Navy procedure for an asphalt-surfaced pavement with 100 percent block cracking (pattern cracking) is 10 square feet per 10 square feet. The weighted defect density is calculated as the defect density times defect severity weight. Assuming a defect severity weight of 3.0 (Table 4), the weighted defect density is 10.0 x 3.0 = 30. The reason for such a high score is that the Navy procedure considers the impact of a defect's density to be linear, an assumption on the project staff found to be invalid during field surveys.

SUMMARY

Ratings determined from the procedures currently being used by the Air Force and Navy were found to have poor correlation with pavement condition ratings made by a group of experienced pavement engineers. Two of the reasons for this poor correlation are applicable to both procedures:

1. Distress severity is not considered; i.e., a hairline crack is counted as being equal to a severely spalled crack.

2. The procedures used to assign a pavement condition rating (based on inspection results) are inadequate; e.g., the impact of each distress is added linearly to obtain the pavement condition rating (especially in the Navy procedure), a practice which tends to underrate the pavement condition.

Based on these findings, it was concluded that a meaningful pavement condition rating can only be obtained by appropriately combining the effects of pavement distress types, densities, and severities. This combined effect should be field tested, improved, and validated through a comparison with ratings obtained by experienced pavement engineers.

SECTION III

AIRFIELD PAVEMENT DISTRESS ANALYSIS

Developing a pavement condition index requires that each type of distress existing in the type of pavement under evaluation be identified and described. This chapter provides information about the types and frequency of occurrence of different distresses found on jointed concrete and asphalt- or tar-surfaced airfield pavements. The information was derived from surveys of 123 pavement sections located at nine airfields (Figure 1) subjected to different environmental and traffic conditions. Descriptions of distress types and severity levels, photographs, and measurement criteria are presented in Volume II of this report.

DISTRESS ON JOINTED CONCRETE PAVEMENTS

Appendix B presents distress types, severities, and densities found on 40 jointed concrete pavement sections. Table 7 summarizes the distress types and percent slabs containing each distress type for surveyed pavements at each airfield. The following conclusions are based on the results presented in the table:

1. The most common distress types found on jointed concrete pavements are:

   a. Longitudinal/transverse/diagonal cracks

   b. Scaling/map cracks/crazing

   c. Patching, less than 5 square feet

Each of these distress types occurred in approximately 20 percent of the surveyed slabs.

2. Approximately 5 percent of the slabs contained corner breaks, shrinkage cracks, joint spalling, and corner spalling.

3. Approximately 3 percent of the surveyed slabs were shattered.

4. Jointed seal damage was found in most of the airfields. No percentage of slabs containing this distress is given, since it is not counted on a slab-by-slab basis. Joint seal damage ratings are based on the condition of the sealant over the entire pavement section.

5. "D" cracking and popouts[6] were only found at Wright-Patterson AFB and Scott AFB. This can be explained by the many freeze-thaw cycles

[6] Popouts were only recorded when the average popout density exceeded three popouts per square yard.

TABLE 7. PERCENT SLABS CONTAINING EACH DISTRESS TYPE IN SURVEYED JOINTED CONCRETE PAVEMENTS

LOCATION AND NO. OF SURVEYED SLABS

Distress type	Craig 80[a]	Eielson 18	Elmendorf 61	George 52	Homestead 312	Scott 124	Wainwright 60	Williams 176	Wright-Patterson 164	Total 1047
Blow-up										0
Corner break				9.62	7.05	2.42	31.67	6.25		5.73
Longitudinal/ transverse/diag. cracking	30.00[b]		11.48	19.23	8.33	14.52	18.33	37.50	26.83	19.68
"D" cracking						1.61			19.51	3.25
Joint seal damage	x	x	x	x	x	x	x	x		x
Patching < 5 sq ft	10.00		6.56	9.62	6.41	15.32	1.67	11.93	60.98	17.00
Patching/ utility cut	1.25		8.20	5.77			15.00	0.57	0.61	1.91
Popouts						0.81			1.83	0.38
Pumping										0
Scaling/map crack/crazing	1.25		29.51	13.46	42.95	21.77	6.67			18.24
Settlement/fault				3.85		1.61		1.14		0.57
Shattered/slab			24.59	3.85	0.64		15.00	3.41		3.25
Shrinkage crack	1.25			11.54	0.96	5.65	35.00	4.55	1.22	4.58
Spalling, joints		22.22	6.56	9.62	1.60	13.71	5.00	3.98	5.49	5.16
Spalling, corner				7.69	0.32	13.71	3.33	1.14	12.80	4.49

[a]Total number of slabs included in survey at named base

[b]Percent slabs containing each distress type

the pavements in these two areas are subjected to and the aggregate characteristics in the areas.

6. All distress types were found to occur at various severity levels. For example, cracks were found to be hairline on some slabs and severely spalled on others.

DISTRESS ON ASPHALT- OR TAR-SURFACED PAVEMENTS

Appendix C presents the distress types, severities, and densities found on 83 asphalt- and tar-surfaced pavement sections. Table 8 summarizes the distress types and percent area containing each distress for surveyed pavements at each airfield. The following conclusions are based on the results presented in the table:

1. The most common distress type is block cracking, which was present on approximately 20 percent of the area surveyed. This is partly due to the fact that most of the airfield pavement is not subjected to traffic (especially near the pavement edges); in warm climates, such areas tend to block crack faster than traffic areas due to hardening of the asphalt. Block cracking caused by severe cold weather can be seen in Eielson AFB (about 60 percent) where the temperature drops to approximately -60°F. High solar radiation in southern regions can also cause asphalt hardening and resulting block cracking, as can be seen in George, Williams, and Homestead AFBs.

2. Each of the following distresses occurred on 3 percent of the surveyed area:

a. Alligator or fatigue cracking

b. Longitudinal and transverse cracking[7]

c. Raveling/weathering.

3. All distress types occurred at various degrees of severity. For example, rutting was 0.25 inch deep on some pavements and 2.0 inches on others.

[7]Longitudinal and transverse cracking and joint reflection cracking are shown in terms of feet/100 square feet, which is equivalent to percentage.

TABLE 8. PERCENT AREA CONTAINING EACH DISTRESS TYPE IN SURVEYED ASPHALT- OR TAR-SURFACED PAVEMENTS

LOCATION AND TOTAL AREA SURVEYED, SQUARE FEET

Distress Type	Craig 34008[a]	Eielson 47640	Elmendorf 51676	George 40700	Homestead 39810	Scott 161190	Williams 51000	Wright-Patterson 37660	Total 463684
Alligator cracking		0.65 308	0.16 83	10.10 4111	6.37 2534	2.30 3713	0.45 227		2.37 10976
Bleeding				0.39 159					0.03 159
Block cracking	1.76[b] 600[c]	60.50 28820	5.74 2964	56.35 22933	38.88 15480	2.48 4000	39.22 20000	1.56 586	20.57 95383
Corrugation									
Depression	0.99 337		0.09 48	0.04 15	0.45 180	0.00 6	0.10 53		0.14 639
Jet blast		7.87 3750						0.08 30	0.82 3780
Joint reflection from PCC			1.03 531			1.35 2169	1.57 801	11.52 4339	1.69 7840
Longitudinal and transverse cracking	2.97 1011	4.90 2332	9.31 4811	2.19 892	0.93 372	1.49 2398	2.61 1331	1.59 599	2.96 13746
Oil spillage			0.08 42			0.13 215		0.06 24	0.06 281
Patching	1.74 592	0.11 54	0.03 14	4.73 1924	0.65 260	0.85 1374		0.40 150	0.94 4368
Polished aggregate									
Raveling/weathering	4.47 1521		0.03 16		17.68 7040	0.43 695	0.30 154	3.19 1201	2.29 10627
Rutting		0.08 36		1.75 714	3.37 1340	0.54 877			0.64 2967
Shoving from PCC									
Slippage cracking									
Swelling									

[a] Total square ft of pavement surveyed at designated base

[b] Percent area or linear ft/100 sq ft^2 of each distress type

[c] Square ft or linear ft of each distress type

SECTION IV

AIRFIELD PAVEMENT CONDITION INDEX DEVELOPMENT--CONCEPTS AND THEORY

INTRODUCTION

A comprehensive pavement condition evaluation requires measurement of several condition indicators, including roughness, skid resistance, structural capacity, and surface physical deterioration or distress.[8,9] If all these condition indicators were measured on an airfield pavement section, a complete and thorough evaluation of the section could be conducted to satisfy almost any purpose. However, direct measurement of roughness, skid resistance, and structural capacity requires specialized and very expensive equipment and personnel; consequently, these measurements cannot be performed for routine evaluation. However, considerable field experience has shown that observation of existing pavement physical deterioration or distress provides a useful and important index of the pavement's present condition and also gives an indication of future performance under existing traffic conditions.

The extent of existing pavement distress, which can be determined by physical observation and simple measurements (i.e., using a straightedge and measuring wheel), also provides an indirect measurement of roughness, skid resistance and, in some respects, structural capacity. Existing pavement distress gives a direct measure of present structural integrity and operational surface condition. It also provides an early indication of possible pavement failure and maintenance and repair requirements, and a basis for scheduling more comprehensive evaluation if necessary. This section presents the concepts and theory used to develop a meaningful pavement condition index based on observable pavement distress.

CONCEPTS AND THEORY

The degree of pavement deterioration is a function of:

1. Types of distress

2. Severity of distress, such as spalling of cracks or depth of ruts

[8]M. Y. Shahin and M. I. Darter, "Development of a Pavement Evaluation System," *Proceedings of an ASCE Specialty Conference on Pavement Design for Practicing Engineers*, co-sponsored by Georgia Institute of Technology, June 1975.

[9]M. Y. Shahin and M. I. Darter, *Pavement Functional Indicators*, Technical Report C-15/ADA007152 (Construction Engineering Research Laboratory [CERL], February 1975).

3. Amount or density of distress, which can be expressed as a percentage of the total pavement area.

Each of these distress characteristics has a significant effect on determination of the overall amount of physical pavement deterioration. If any of these three characteristics is ignored, developing a meaningful condition index will be difficult.

Because there are several types of distress, several possible degrees of severity for each type, and a wide range of amount or density for each type, combining the effects of these three characteristics into one index is the major problem in deriving a condition index. Deduct weighting factors are needed for each characteristic. Although several methods for expressing a condition index were evaluated (Appendix D), the following expression represents the most comprehensive and accurate model. It is based on the assumption that the pavement condition can be adequately estimated by summing all visible distresses over their severity and density levels using appropriate weighting factors.

$$PCI = C - \sum_{i=1}^{p} \sum_{j=1}^{m_i} a(T_i, S_j, D_{ij}) \; F(t, d) \qquad \text{[Equation 1]}$$

where PCI = pavement condition index

C = a constant depending on desired maximum scale value

a( ) = deduct weighting value depending on distress type T_i, level of severity S_j, and density of distress D_{ij}

i = counter for distress types

j = counter for severity levels

p = total number of distress types for pavement type under consideration

m_i = number of severity levels on the i^{th} type of distress

F(t, d) = an adjustment factor for multiple distresses that vary with total summed deduct value (t) and number of deducts (d).

A pavement section's PCI can be determined from Equation 1 only when the following are known (Figure 12):

Distress Types

Each distress type[10] existing in the type of pavement under evaluation must be identified and described. Figure 13 shows an example description of alligator or fatigue cracking.

[10] See Section III for a discussion of the distress types found in both jointed concrete and asphalt- or tar-surfaced pavements.

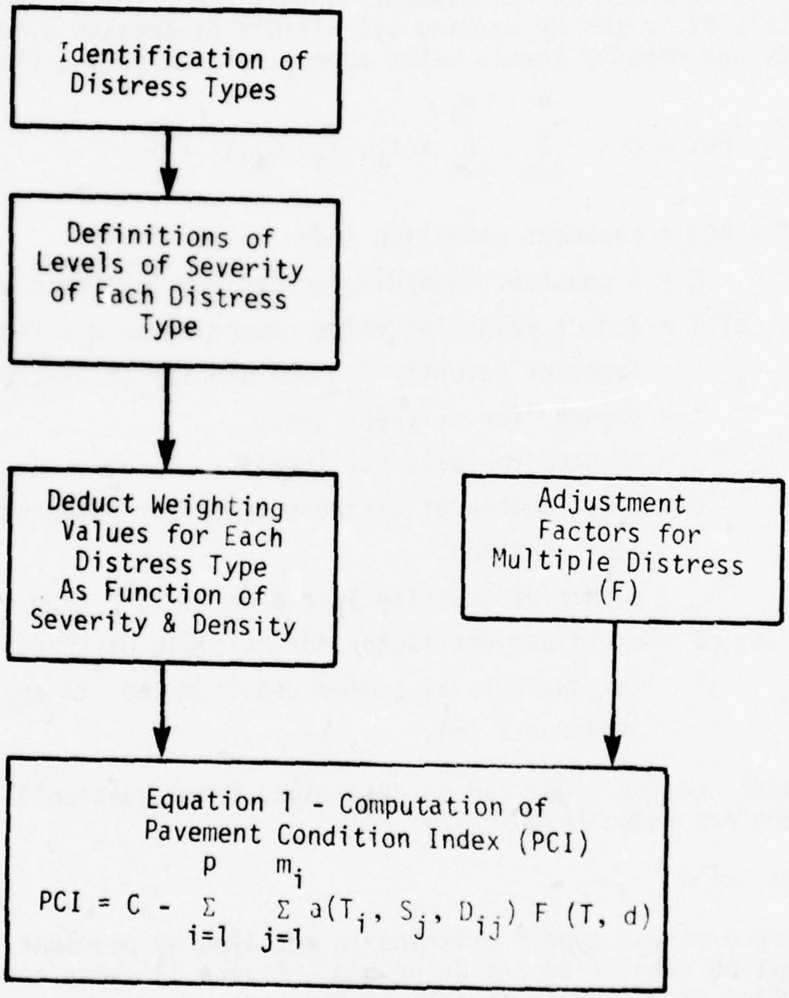

Figure 12. Information Needed to Determine the Pavement Condition Index Using Equation 1.

Name of Distress: Alligator or Fatigue Cracking

Description: Alligator or fatigue cracking is a series of interconnecting cracks caused by fatigue failure of the asphalt concrete surface under repeated traffic loading. The cracking initiates at the bottom of the asphalt surface (or stabilized base) where tensile stress and strain is highest under a wheel load. The cracks propagate to the surface initially as a series of parallel cracks. After repeated traffic loading the cracks connect, forming many-sided, sharp-angled pieces that develop a pattern resembling chicken wire or the skin of an alligator. The pieces are less than 2 feet on the longest side.

Alligator cracking occurs only in areas that are subjected to repeated traffic loadings, such as wheel paths. Therefore, it would not occur over an entire area unless the entire area was subjected to traffic loading. Pattern-type cracking which occurs over an entire area that is not subjected to loading is rated as block cracking, which is not a load-associated distress.

Alligator cracking is considered a major structural distress.

Severity Levels:

L - Fine, longitudinal hairline cracks running parallel to each other with none or only a few interconnecting cracks. The cracks are not spalled.

M - Further development of light alligator cracking into a pattern or network of cracks that may be lightly spalled.

H - Network or pattern cracking has progressed so that the pieces are well defined and spalled at the edges; some of the pieces rock under traffic.

How to Measure: Alligator cracking is measured in square feet of surface area. The major difficulty in measuring this type of distress is that many times two or three levels of severity exist within one distressed area. If these portions can be easily distinguished from each other, they should be measured and recorded separately. However, if the different levels of severity cannot be easily divided, the entire area should be rated at the highest severity level present.

Legend:

L - Low severity level
M - Medium severity level
H - High severity level

Figure 13. Example Description of a Distress and Three Levels of Severity.

Distress Severity

As discussed in Section III, most distress types occur in various levels of severity, which must each be explicitly defined. These definitions must be written so that field engineers can consistently identify a given distress type and severity. Figure 13 also gives example descriptions of the levels of severity of alligator or fatigue cracking.

Deduct Weighting Values--$a(T_i, S_j, D_{ij})$

Deduct values as functions of distress type (T_i), level of severity (S_j), and density (D_{ij}) must be determined. This determination is described in detail later in this section and in Sections V and VI, but an example is given here to illustrate the concept. A major structural distress of asphalt-surfaced pavement is alligator or fatigue cracking (Figure 13). Weighting deduct values must be determined over a range of density (i.e., percent area) of distress. The deduct values must be based on some selected rating scale, such as a scale ranging from 0 to 100, with 0 deduct indicating the distress has no impact on pavement condition and 100 deduct indicating an extremely serious distress which causes the pavement to fail. Deduct values can then be assigned to a given density and level of severity based on the impact of the distress on pavement condition, as discussed in Section V. Figure 14 gives example deduct value curves for alligator cracking for three levels of severity (low, medium, and high), and densities ranging from 0.1 to 50 percent of total pavement area. A pavement section having 1 percent of light alligator cracking would have a deduct value of 22, and the PCI (maximum = 100) would be:

$$\text{PCI} = 100 - (22)(1.0) = 78$$

Curves like those shown in Figure 14 must be derived for each distress type and level of severity. These curves are based on the assumption that only one distress type at a given level of severity exists in the pavement section, and are based on a scale from 0 to 100.

Adjustment Factor for Multiple Distress Types (F)

An adjustment factor must be developed so that pavement sections having more than one distress can be evaluated using the curves described above. The deduct values are not linearly additive, because as additional distress types and/or severity levels occur in a given pavement section, the resulting impact of those distresses become smaller. For example, for a pavement section containing three distress types, the deduct values are determined based on individual distress ratings (Table 9). The total deduct value for the distresses shown in the table is 57 points; however, the PCI cannot be determined by subtracting 57 points from 100, because the deduct values were originally developed for only one distress type. The total must be modified by a factor F which is a function of the magnitude of the total deduct and the number of deducts (three in this example):

$$F = f\text{ (magnitude of total deducts, number of deducts)}.$$

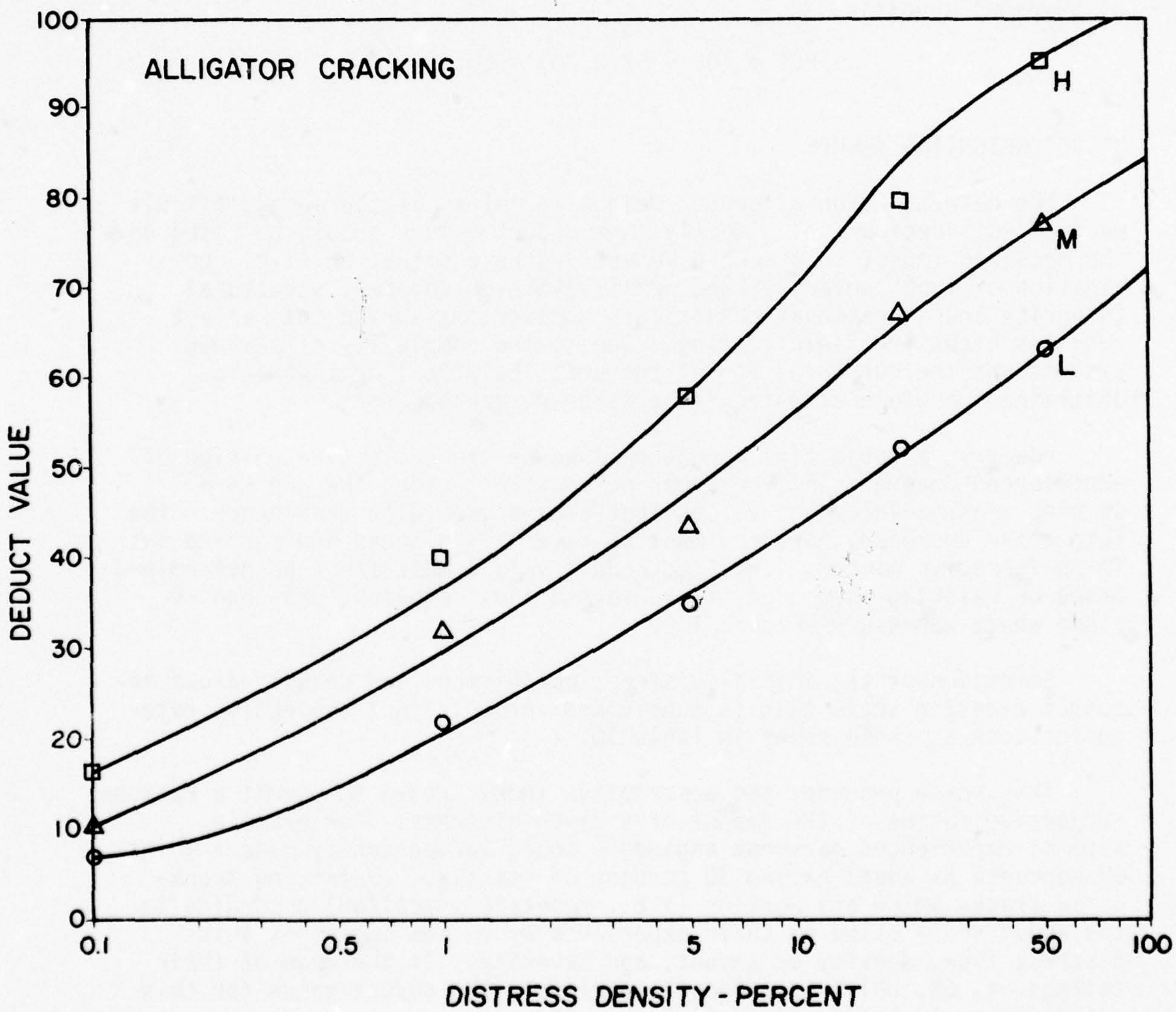

Figure 14. Example of Deduct Value vs Density Curves for Alligator Cracking.

TABLE 9. EXAMPLE OF CALCULATION OF DEDUCT VALUES

Distress Type	Density	Severity	Deduct Values
Alligator Cracking	1 percent	Light	22 pts
Rutting	1 percent	Light	15 pts
Raveling	10 percent	Medium	20 pts
	Total Deduct Value		57 pts

The function F is derived from experimental rating data, as described in Sections V and VI. The value of F in this example, as determined in Section VI, is 0.70; hence a PCI which gives a more accurate estimation of pavement condition is

$$PCI = 100 - 57(0.70) = 60.$$

DEDUCT WEIGHTING VALUES

The determination of deduct weighting values is the most difficult part of PCI development. Ideally, the deduct values should be based on the measured impact that each pavement distress situation (i.e., combination of type, severity, and density) has on pavement structural integrity and operational condition. However, measuring this effect requires extensive field testing. Due to the complexity of pavement systems and the current state of the art, analytical or theoretical determination would also require a large research effort.

However, a subjective approach based on the collective opinion of experienced pavement engineers can be used to "bridge the gap" and develop reasonable deduct values that can be used with confidence. The subjective approach, however, must be carefully planned and carried out in an iterative manner; i.e., the deduct values must first be determined based on existing knowledge, field tested and evaluated, and then revised where necessary (Figure 15).

Selection of the initial distress definitions and deduct values requires a rating scale that is subdivided into distinct subjective categories such as those shown in Table 10.

This scale provides the descriptive index needed to permit a rational subjective rating of the impact of a given distress. For example, several experienced pavement engineers could independently rate a jointed concrete pavement having 30 percent of its slabs containing transverse cracks which are working (i.e., moderately spalled) according to the above scale based on their experience as to the impact of this distress type, density or amount, and severity. If the mean of their ratings was 65, which is a "good" condition, the deduct value for this situation would be 35 points (100-65 = 35).

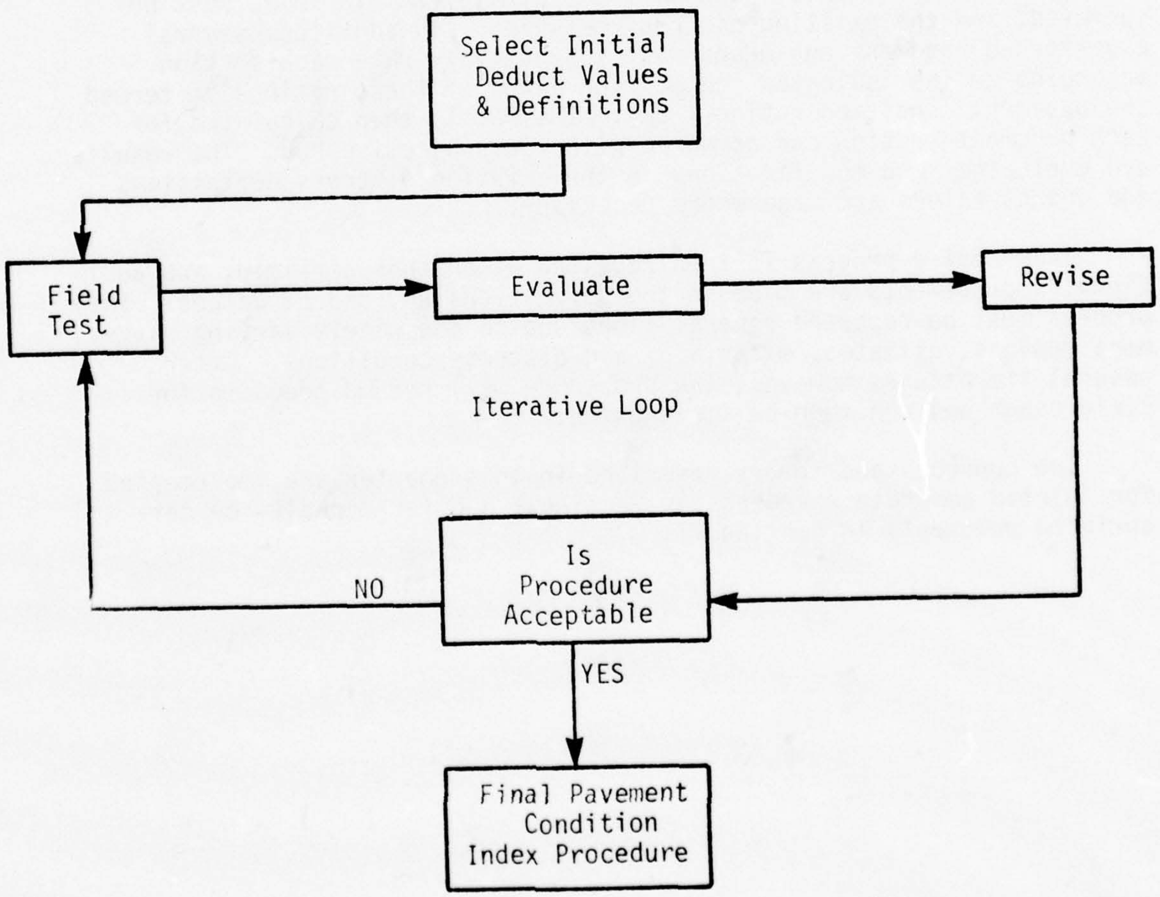

Figure 15. Iterative Procedure to Determine Realistic Distress Deduct Values and Distress Definitions Using a Subjective Approach.

TABLE 10. DESCRIPTIVE RATING SCALE

Rating Scale	Descriptive Categories
100 - 86	Excellent
85 - 71	Very Good
70 - 56	Good
55 - 41	Fair
40 - 26	Poor
25 - 11	Very Poor
10 - 0	Failure

After the first set of definitions has been developed and deduct values determined based on the definitions and experience of the project staff, several pavements, such as those at a given airfield, must be surveyed, and the existing distress measured. In addition, several experienced pavement engineers must subjectively rate each section according to the indicated scale. The means of these ratings is termed the pavement condition rating ($\overline{PCR}$). The PCI is then calculated for each pavement section and compared with the subjective $\overline{PCR}$. The results are evaluated, and modifications in the existing distress definitions and deduct values are made where necessary.

This entire process is then repeated at another airfield, and additional improvements are made in the definitions and deduct values. The process must be repeated several times due to the widely varying pavement designs, climates, materials, and distress conditions. After several iterations, however, the procedure will become adequate for field usage and can then be implemented.

The concepts and theory described in this chapter are implemented for jointed concrete pavements in Section V and for asphalt- or tar-surfaced pavements in Section VI.

SECTION V

PAVEMENT CONDITION INDEX FOR JOINTED CONCRETE PAVEMENT

This section describes details of the development of the PCI for jointed concrete pavements and presents results from the field verification. As described herein, developing an acceptable procedure required many months of trial testing, evaluation, and improvements. Appendix A presents the overall procedure for field usage.

DEVELOPMENT OF DISTRESS DEFINITIONS AND DEDUCT VALUE CURVES

Initial Definitions and Values

The first steps were (1) to review previous literature on concrete pavement distresses[11,12,13,14] and condition survey reports for more than 20 airfields and (2) to observe airfield pavement condition first-hand (at Tinker AFB, OK). Based on these sources of information and the project staff's previous experience, an initial set of distresses was selected and severity levels were defined. Preliminary surveys and discussion with engineering personnel at Tinker indicated that a "sample unit" of approximately 20 slabs would provide an adequate area of pavement for evaluation and computation of PCI. An area of 20 slabs is large enough for meaningful distress measurement, and any large pavement feature can be divided into sample units of about 20 slabs. The amount (or density) of distress was determined by counting the number of slabs in the sample unit that had a particular distress at a particular level of severity, and dividing it by the total number of slabs in the sample unit.

Initial weighting deduct values were determined based on the limited experience gained thus far. The deduct values were set according to the scale in Table 10 by subjectively estimating the maximum deduct for each distress and severity level at a maximum density, and then assuming a curvilinear relationship between the deduct value and density. Deduct value versus density curves were derived in this manner for each distress type and level of severity.

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[11] E. J. Barenberg, C. L. Bartholomew, and M. Herrin, *Pavement Distress Identification and Repair*, Technical Report P-61/AD758447 (CERL, March 1973).

[12] M. Y. Shahin, M. I. Darter, and F. M. Rozanski, *Pavement Inspection Reference Manual*, Technical Information Pamphlet C-48/ADA017329 (CERL, September 1975).

[13] *Standard Nomenclature and Definitions for Pavement Components and Deficiencies*, Special Report (Highway Research Board, 1970).

[14] M. I. Darter and E. J. Barenberg, *Zero Maintenance Pavement: Performance Capabilities and Requirements*, Preliminary Interim Report (University of Illinois, 1975).

The PCI of the pavement section was calculated by the following expression:

$$PCI = 100 - \sum_{i=1}^{p} \sum_{j=1}^{m_i} a(T_i, S_j, D_{ij}) \qquad \text{[Equation 2]}$$

where: $a(T_i, S_j, D_{ij})$ = deduct value for a given distress type T_i, at a severity level S_j, and density D_{ij}

i = counter for distress types

j = counter for severity levels

p = total number of distress types

m_i = number of severity levels of the ith type of distress.

This expression provides that the PCI can be determined by adding all individual deduct values, a( ), that exist for a pavement section and subtracting the total from 100.

First Field Test, Evaluation, and Revision

A field test of the initial procedures was conducted on five jointed concrete pavements at Wright-Patterson AFB, OH. Each section was surveyed, all distresses were recorded, and a PCI for each section was computed according to Equation 2. Four experienced pavement engineers (two members of the project staff, the major command pavement engineer, and the base pavement engineer subjectively rated each pavement section using the rating form in Figure 16. The major criteria for rating were pavement structural integrity and operational surface condition. The average of the four engineers' pavement condition ratings was computed for each section and called the pavement condition rating ($\overline{PCR}$).

Evaluation of the results obtained indicated two major deficiencies:

1. The definitions of several distress types and levels of severity did not describe actual conditions adequately.

2. The calculated PCIs for all five sections were much lower (i.e., 30 to 65 points) than the average subjective $\overline{PCR}$s of the engineers.

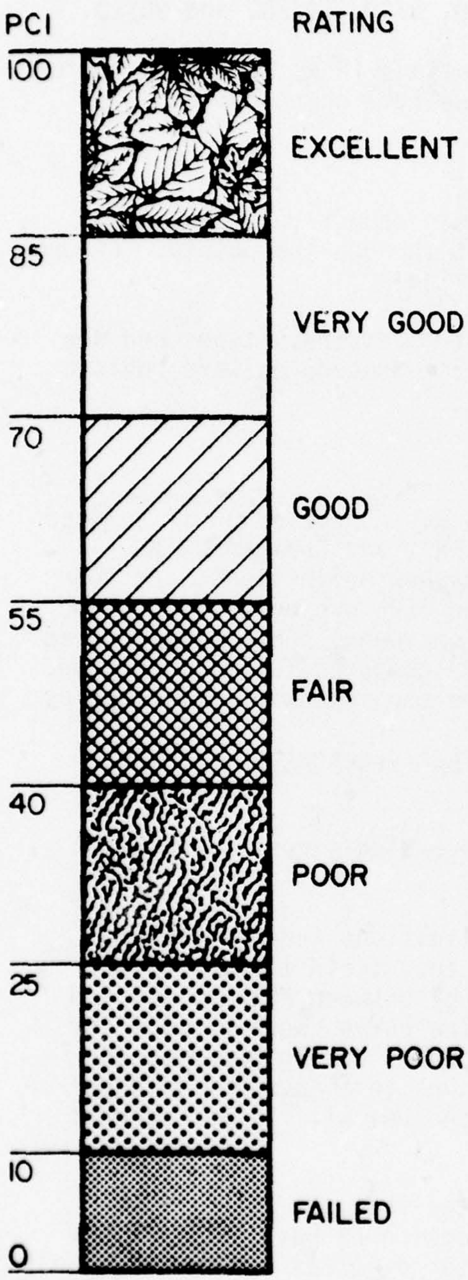
Therefore, the procedures, including both the distress definitions and deduct values, were extensively revised. The definitions of distress were revised using the numerous slides taken at Wright-Patterson and Tinker AFBs and discussions with the major command engineer.

The deduct value curves for each distress type at a particular level of severity were revised in the following manner:

1. Pavement sections containing a total of 20 slabs (and varying amounts of distress) were subjectively rated independently by three

AIRFIELD:____________________ FEATURE NO:__________________

DATE:________________________ INSPECTOR:__________________



INSTRUCTIONS: Please rate pavement with regard to its overall structural integrity and operational condition (excellent rating indicates none or very minor distress present and very poor rating indicates severe distress and imminent failure).

On the rating scale shown here, how would you rate this feature?

____

____

Give an approximate numerical score.

____

Major factors influencing your rating:

____

____

____

____

____

____

Figure 16. Subjective Rating Form Used by Pavement Engineer.

project staff engineers according to the scale in Figure 16. Each rater gave the pavement section a subjective rating such as "excellent," "good," . . . . or "failed," and a numerical value within that rating.

2. The ratings were made for four to five levels of density (or amount). For example, linear cracking was rated at density levels of 1 slab cracked per 20 slabs, or 1/20, and 3/20, 5/20, 10/20, and 20/20.

3. The mean of the three subjective ratings ($\overline{PCR}$) was computed for each density level, and the mean deduct value ($\overline{DV}$) computed as:

$$\overline{DV} = 100 - \overline{PCR}$$

A plot of density of distress versus mean deduct value was developed, and a best fit smooth curve was fit through the points. Figure 17 illustrates these curves for linear cracking.

This procedure was repeated for each of 15 distress types and one to three levels of severity of each type. The procedures were revised and prepared for additional field testing.

Second Field Test, Evaluation, and Revision

A field test of the revised procedures was conducted on 11 jointed concrete pavement sections at Williams AFB, AZ, and Craig AFB, AL. Distress data were recorded according to the new definitions, and four experienced pavement engineers (two from the CERL project staff, the major command engineer, and the local base engineer) subjectively rated each section. The PCI and the mean $\overline{PCR}$ were computed for each section. Evaluation of the results obtained indicated the following deficiencies:

1. Some of the definitions did not clearly describe existing distresses.

2. The PCIs of sections containing several distress types were significantly less than the $\overline{PCR}$s.

Therefore, several of the distress definitions were revised to reflect the experience gained during the second field test. Further consideration and analysis of the discrepancy between PCI and $\overline{PCR}$ led to the conclusion that since the deduct value curves were derived for only one distress type, the deduct values cannot simply be added together when more than one distress type occurs in a pavement section. A correction factor must be applied so that the PCI will better predict the $\overline{PCR}$.

Analysis of the available data indicated that the total deduct value (i.e., the sum of all deducts in a section of pavement) must be adjusted to reflect the number of deducts (or distress types plus levels of severity) and the magnitude of the total deduct value.

This adjustment function for multiple distresses was determined by subjectively rating many pavement sections containing from two to eight

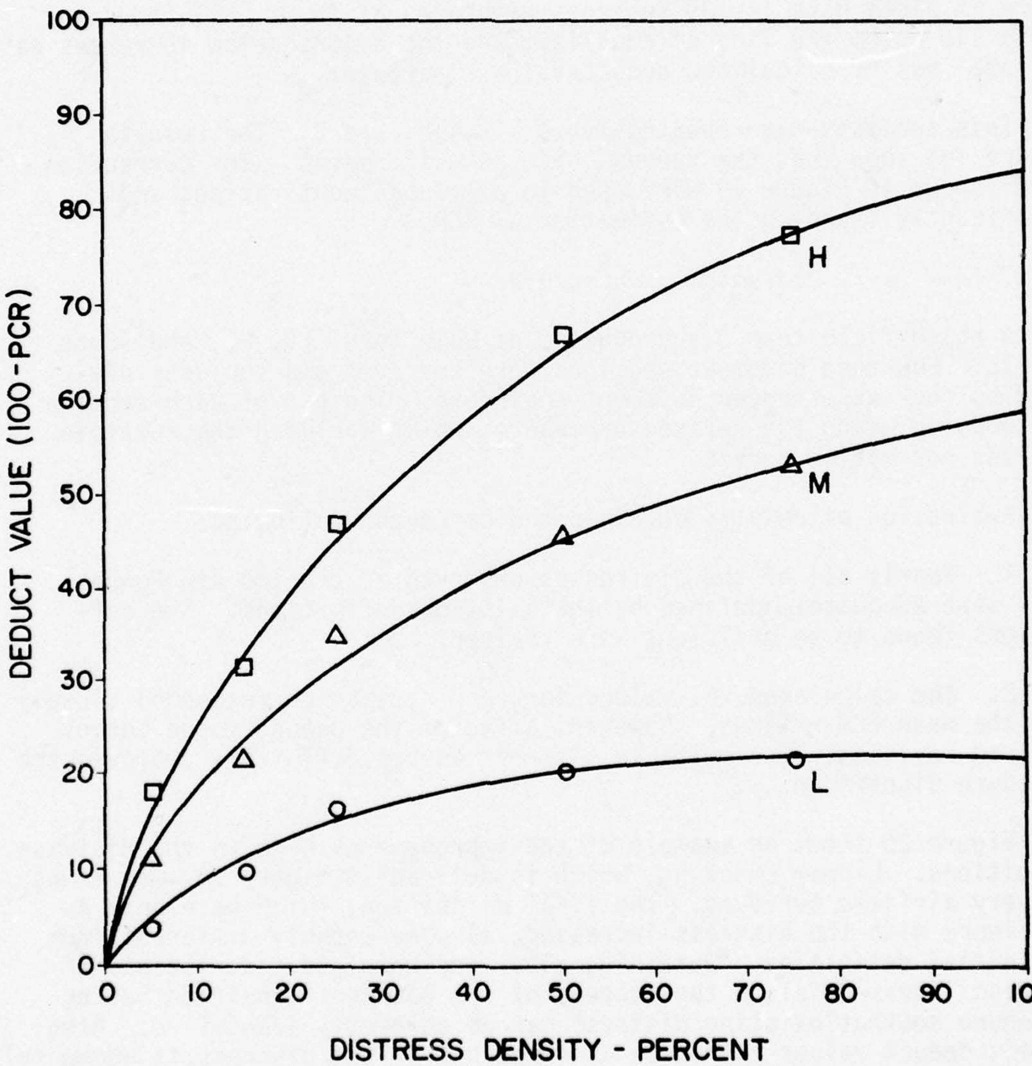


Figure 17. Example Showing How Deduct Values Curves Were Developed for Linear Cracking. (Longitudinal, Transverse, and Diagonal Cracking)

distress types and/or levels of severity. The total sum of calculated deduct values determined using the individual deduct value curves and the corrected deduct value determined by subtracting the $\overline{PCR}$ from 100 for each section were then plotted; Figure 18 shows an example plot for a section where q = 3 (q is the number of distress types at specific levels of severity with deduct values exceeding 5). The reason for only counting deduct values greater than 5 is that the data indicate that smaller deducts have little effect on pavement condition. For example, a pavement might have eight distresses that are mostly minor; thus, the correction curves for q = 8 would give too large an adjustment.

Table 11 presents data for an example 20-slab section with q = 3. The mean $\overline{PCR}$ of this section is 74, and hence the corrected deduct value is 100 - 74 = 26. This result indicates that the total deduct value of 46 shown in Table 11 is too large and must be adjusted toward 26. Figure 18 plots data for 39 sections with q equal to 3. All the data points lie below the line of equality, and the extent below increases as the total sum of calculated deduct values increases.

This analysis was repeated for q = 2,4,6, and 8. The results (Figure 19) show that the curves shift as q increases. The correction curves shown in Figure 19 were used in all subsequent ratings and significantly improved the estimation of $\overline{PCR}$.

Third Field Test, Evaluation, and Revision

A third field test was conducted at Homestead AFB, FL, and Scott AFB, IL. Fourteen pavement sections were surveyed and subjectively rated by four experienced pavement engineers. The PCI of each section was computed using the revised procedure, which included the multiple distress correction curves.

Evaluation of results obtained indicated the following:

1. Nearly all of the distresses observed at the two Air Force bases were adequately defined by the existing definitions. The definitions found to be deficient were revised.

2. The calculated PCI values for each section corresponded closely with the mean $\overline{PCR}$ ratings. However, a few of the deduct value curves required revision. The multiple distress curves definitely improved the procedure significantly.

Figure 20 shows an example of the improvements made in the distress definitions. Linear cracking, which is defined in Figure 20, was found at every airfield surveyed. The final definition, which developed as experience with the distress increased, is considerably different from the initial definition. Obtaining clear and complete descriptions of distress is essential to the success of the pavement condition rating procedure so that existing distress can be correctly identified. Also, correct deduct values cannot be assigned unless the distress is adequately identified and defined.

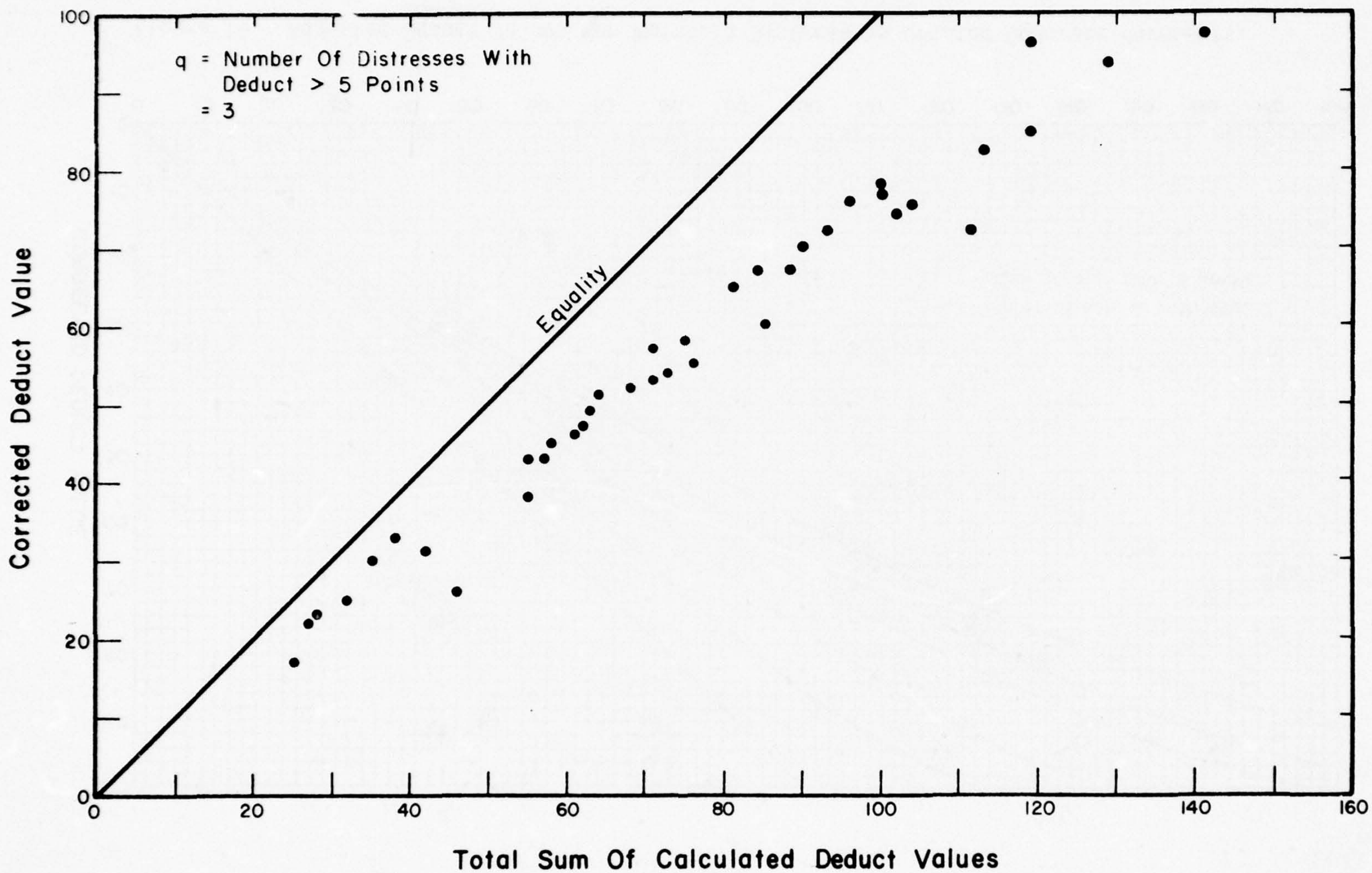


Figure 18. Example Correction Curve for Multiple Distress Types.

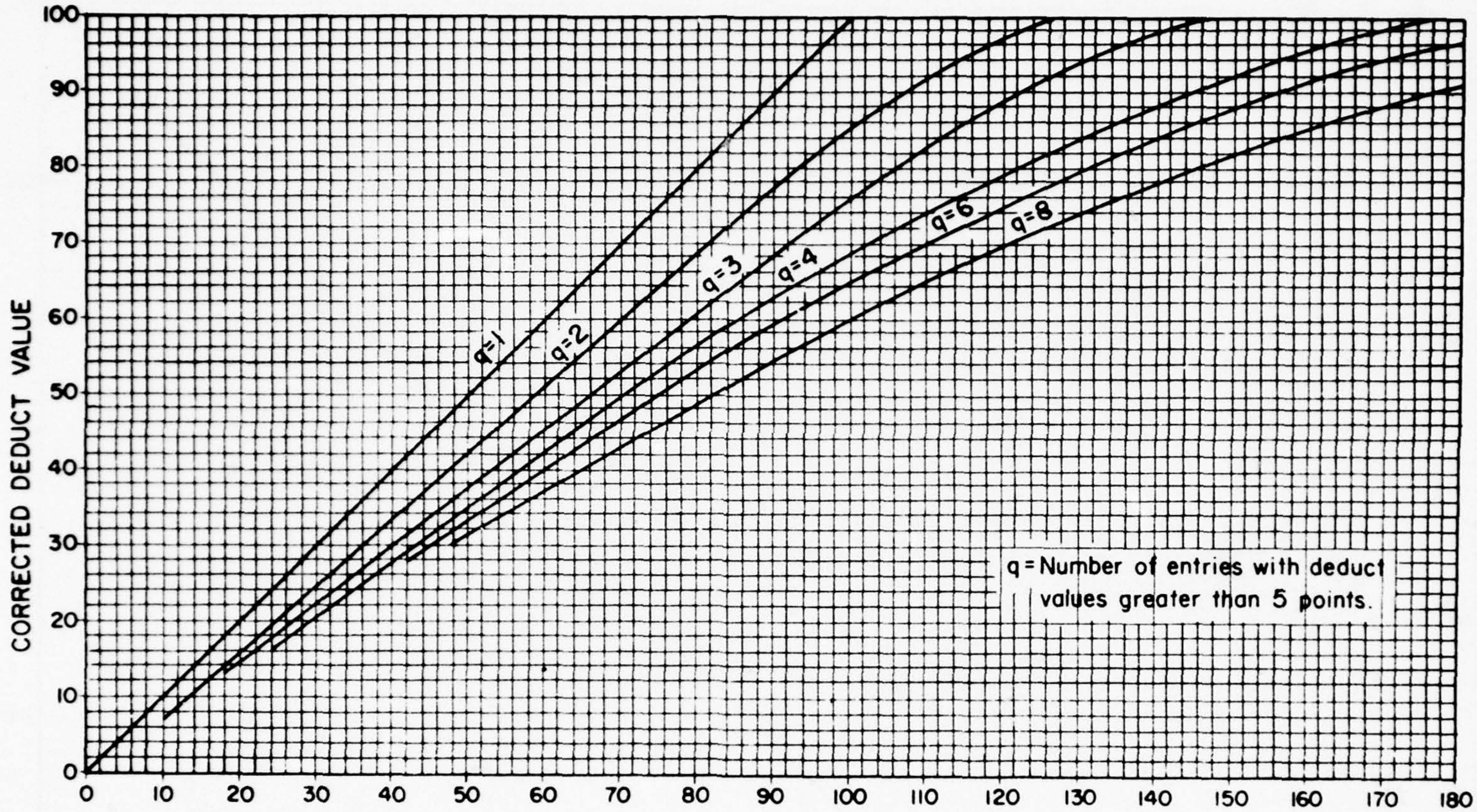


Figure 19. Adjusted Deduct Values for Multiple Distress in Jointed Concrete Pavements.

INITIAL DEFINITION

Name of Distress:	Longitudinal, Transverse, Diagonal, and Corner Cracks
Description:	These cracks divide the slab into two or three pieces. (If the slab is divided into four or more pieces, it is shattered.)
Severity Levels:	H - Cracks dividing the slab into two pieces that are wide (average more than 3/4 in.) and badly spalled; cracks that are moderately wide (average 1/4 in. - 1 3/4 in.) and/or moderately spalled and divide the slab into three pieces.
	M - Cracks that are moderately wide (average 1/4 in. - 3/4 in.) and/or moderately spalled that divide the slab into two pieces; narrow cracks (average less than 1/4 in.) and/or slightly spalled cracks that divide the slab into three pieces.
	L - Narrow (average less than 1/4 in.) and/or slightly spalled cracks that divide the slab into two pieces.

Figure 20. Initial and Final Description and Definition of Linear Cracking.

FINAL

Name of Distress: Longitudinal, Transverse, and Diagonal Cracks

Description: These cracks, which divide the slab into two or three pieces, are usually caused by a combination of load repetition, curling stresses, and shrinkage stresses. (Slabs divided into four or more pieces are considered shattered.) Low-severity cracks are usually warping- or friction-related and are not considered major structural distresses. Medium or high severity cracks are usually working cracks and are considered major structural distresses.

NOTE: Hairline cracks that are only a few feet long and do not extend across the entire slab are rated as shrinkage cracks.

Severity Levels:

L - (1) crack has no spalling or minor spalling (no FOD potential). If nonfilled, it is less than 1/8 in. wide; a filled crack can be of any width, but its filler material must be in satisfactory condition.

M - One of the following conditions exists: (1) a filled or nonfilled crack is moderately spalled (some FOD potential); (2) a nonfilled crack has a mean width between 1/8 in. and 1 in.; (3) a filled crack has no spalling or minor spalling, but the filler is in unsatisfactory condition; or (4) the slab is divided into three pieces by low severity cracks.

H - One of the following conditions exists: (1) a filled or nonfilled crack is severely spalled (definite FOD potential); (2) a nonfilled crack has a mean width approximately greater than 1 in., creating tire damage potential; or (3) the slab is divided into three pieces by two or more cracks, one of which is at least medium severity.

How to Count: Once the severity has been identified, the distress is recorded as one slab.

Figure 20. Initial and Final Description and Definition of Linear Cracking (concluded).

TABLE 11. EXAMPLE JOINTED CONCRETE PAVEMENT SECTION DATA

Distress	Density	Deduct Value
Linear Cracking		
light severity	2/20 slabs	9
medium severity	1/20 slabs	12
Corner Spall		
light severity	2/20 slabs	4
Crazing		
light severity	2/20 slabs	4
Corner Break		
medium severity	2/20 slabs	15
Small Patch		
light severity	2/20 slabs	2
	Total deduct value =	46
	q = number of deducts >5 =	3

ILLUSTRATION OF DEDUCT VALUE CURVES

The deduct value curves for the 15 distress types differ considerably. Figure 21 shows the effect of different distress types (for a medium severity level for example) on deduct values. Most of the curves have similar shapes, but their effects on the PCI differ greatly. Shattered slabs have a much larger deduct value than does shrinkage cracking, for example. Table 12 shows the PCI values for a pavement section with 10 out of 20 slabs having various distress at a medium severity level.

Figure 17 shows typical differences between the deduct value curves for the three levels of severity of linear cracking (defined in Figure 20). Table 13 shows the deduct values obtained in a pavement section if 5 out of 20 slabs are cracked.

The data in Table 13 show that a 20-slab section of jointed concrete pavement containing five slabs with linear cracking (longitudinal, transverse, or diagonal cracks), has a PCI of 55 to 85 and a rating of "fair" to "very good," depending on the severity of the cracks, even though the density of cracking is the same.

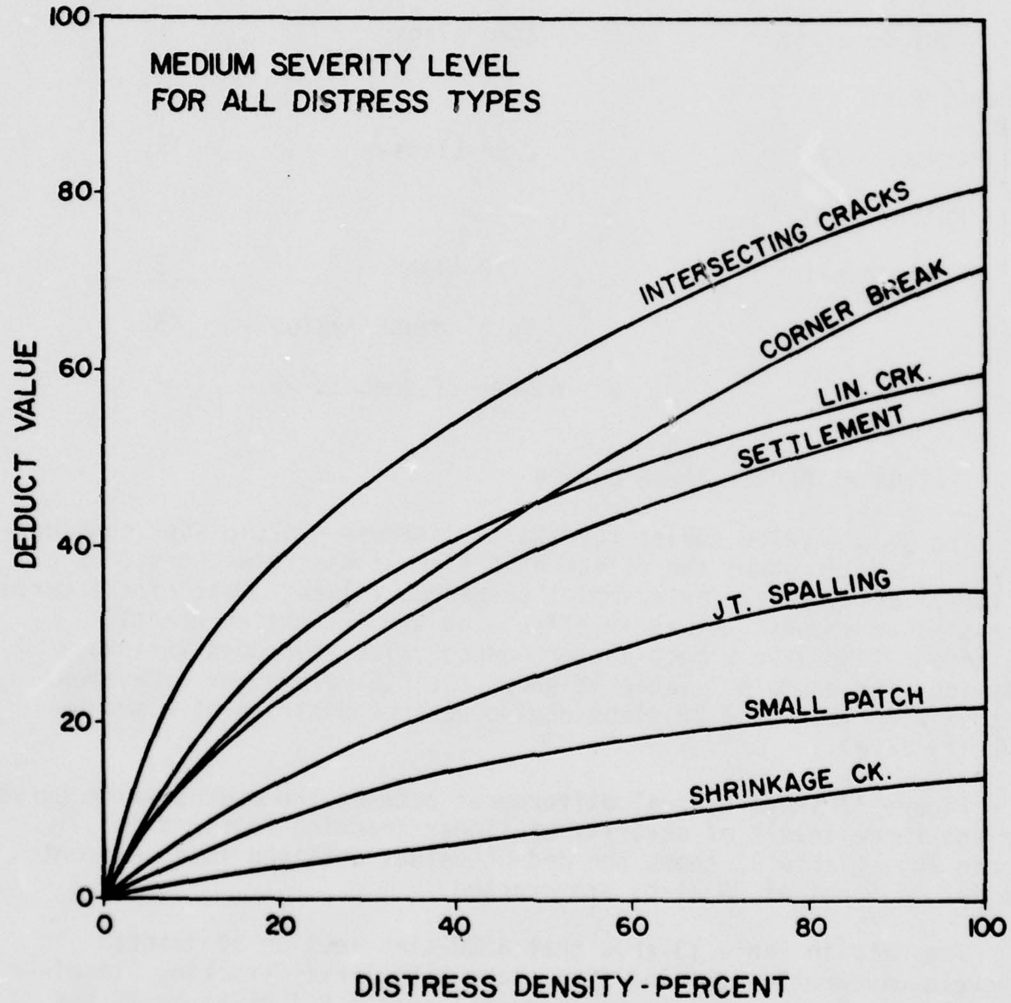


Figure 21. Illustration of Deduct Value Curves for Several Distress Types, All Distresses at Medium Severity Levels.

TABLE 12. PCI VALUES FOR DIFFERENT DISTRESS TYPES IN JOINTED CONCRETE PAVEMENT

Distress	Deduct Value	PCI	General Condition
Shrinkage Crack	8	92	Excellent
Joint Spall	25	75	Very Good
Settlement	40	60	Good
Linear Crack	45	55	Fair
Shattered Slab	60	40	Poor

TABLE 13. DEDUCT VALUES FOR DIFFERENT LEVELS OF SEVERITY OF LINEAR CRACKING

Severity	Deduct Value	PCI	Rating
Low	15	85	Very Good
Medium	32	68	Good
High	45	55	Fair

The general shape of the curves is significant because it indicates the relative effect that amount or density of distress has on pavement condition. The deduct values increase rapidly up to about 50 percent cracked slabs and then level off. Hence the initial development of linear cracking in jointed concrete slabs has a very significant impact on pavement condition.

EXAMPLE CALCULATION OF PCI

This section illustrates the calculation of the PCI for a taxiway at Homestead AFB, FL. The taxiway is 50 feet wide and has 25 x 25 feet slabs. To determine the section's PCI, a two-slab-wide and 10-slab-long section of the taxiway is surveyed. The section is diagramed on the final condition data sheet used for jointed concrete pavements (Figure 22). The distress occurring in each slab is recorded as indicated. For example, the slab at the lower left has 3L and 10L, which are coded to distress types as shown on the data sheet:

3L -- Low-severity longitudinal, transverse, or diagonal crack.

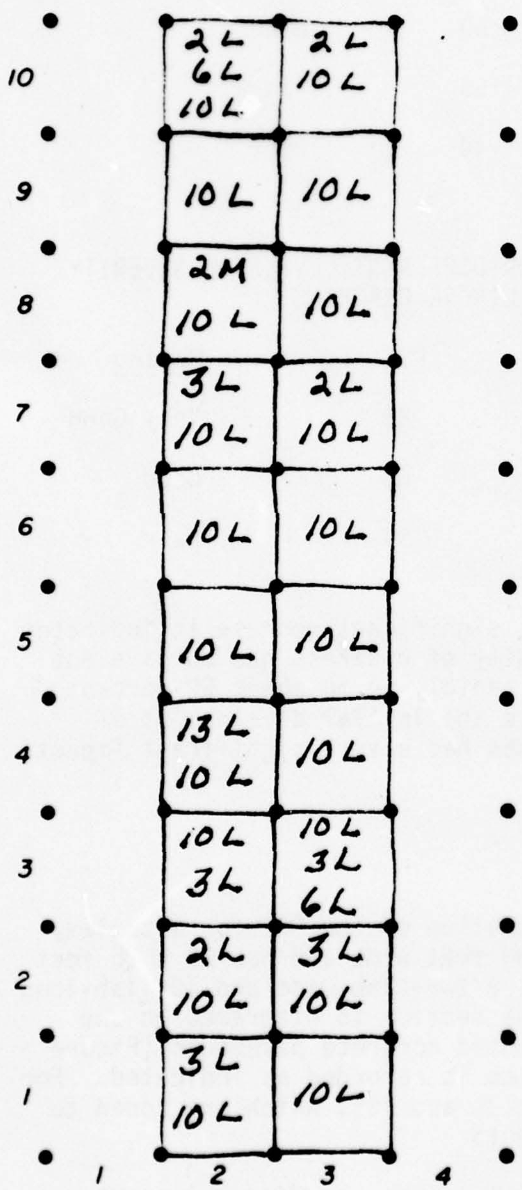
10L -- Low-severity scaling or map cracking or crazing.

JOINTED CONCRETE PAVEMENT
CONDITION SURVEY DATA SHEET FOR SAMPLE UNIT

AIRFIELD Homestead AFB FEATURE TW1

DATE 3/28/76 SAMPLE UNIT 1

SURVEYED BY MS/MD SLAB SIZE 25 x 25 ft
20 slabs



Distress Types

1. Blow-Up
2. Corner Break
3. Long/Trans/Diag. Crk
4. "D" Crk
5. Joint Seal Damage
6. Patching, <5ft²
7. Patching/Utility Cut
8. Popouts
9. Pumping
10. Scaling/Map Crk/Crazing
11. Settlement/Fault
12. Shattered Slab
13. Shrinkage Crk
14. Spalling, Joints
15. Spalling, Corner

DIST. TYPE	SEV.	NO. SLABS	% SLABS	DEDUCT VALUE
2	L	4	20.0	15
2	M	1	5.0	8
3	L	5	25.0	16
6	L	2	10.0	2
10	L	20	100.0	17
13	L	1	5.0	1

DEDUCT TOTAL	59
CORRECTED DEDUCT VALUE (CDV) q = 4	42

PCI = 100 − CDV = 58

RATING = GOOD

Figure 22. Condition Survey Data Sheet for Example Calculation of PCI.

The deduct values for each distress are determined from the deduct curves presented in Appendix A, Figure A-4. These deducts are then summed to give 59. Since there are four deduct values greater than 5, the 59 value must be adjusted using the q = 4 curve in Figure 19. The adjusted deduct value is 42. The PCI is then calculated to be 58, which indicates a low "good" rating. The subjective ratings for this section were 50, 58, 60, and 70 for a mean $\overline{\text{PCR}}$ of 59.5.

EVALUATION AND FIELD VALIDATION

Evaluation

The pavement condition rating procedure was evaluated using results from all 30 sections at the five airfields. The PCI of each of the 30 sections was computed using the revised procedure, and these results were compared with the mean subjective ratings ($\overline{\text{PCR}}$) of experienced pavement engineers. Table 14 summarizes these data. Results showed that:

1. The overall average $\overline{\text{PCR}}$ and PCI of all sections at each of the five airfields compare very closely (within 2 points).

2. The mean absolute difference between the $\overline{\text{PCR}}$ and PCI for all sections is relatively small (5.2 points). The differences range from 0 to 14 points.

Field Validation

Although these results provided strong field verification of the procedure and the calculated PCIs appeared to predict closely the mean subjective opinion of experienced pavement engineers, additional tests were still believed to be necessary to test the procedure with data other than that from which it was developed.

Four additional airfields (George AFB, CA, Elmendorf AFB, AK, Eielson AFB, AK, and Fort Wainwright, AK) were visited and 10 jointed concrete pavement sections were surveyed. Table 15 summarizes the results obtained from these bases. The mean absolute difference between $\overline{\text{PCR}}$ and the calculated PCI is 3.5 points, which is less than the 5.2 mean difference for the original 30 sections. The differences range from 1 to 6 points. The overall mean $\overline{\text{PCR}}$ of all the sections is 48, and the mean PCI is 46.

The $\overline{\text{PCR}}$ was subjectively rated by two CERL project staff engineers and the base or major command pavement engineers for the bases evaluated. A few deficiencies in the distress definitions and deduct curves were identified and corrected.

The differences between $\overline{\text{PCR}}$ and PCI can be compared to the range of differences between the individual raters for each airfield. For example, at Homestead AFB, the mean absolute difference between the $\overline{\text{PCR}}$ and the PCI is 4.0 points for 10 sections. However, the mean range

TABLE 14. SUMMARY OF PCI AND $\overline{PCR}$ DATA FROM FIELD SURVEYS AT FIVE AF BASES FOR JOINTED CONCRETE PAVEMENTS

Pavement Location	Pavement Feature		Mean $\overline{PCR}$	PCI
Wright-Patterson AFB, OH	R6B		85	82
	R10D		68	65
	T7C		41	50
	T2A		80	72
	A14B		81	74
		Mean	71	69
Williams AFB, AZ	R30L(M9/1)		45	41
	R30R(M8/1)		89	93
	R30L(M6/4)		90	91
	TW6		49	57
	A1		64	70
	A2		50	46
	A3		37	26
		Mean	61	61
Craig AFB, AL	R14L		93	96
	R321		57	45
	A1		76	71
	A1		85	89
		Mean	78	76
Homestead AFB, FL	R35(END)		89	89
	R35(1)		77	84
	R35(13)		91	93
	R35(20)		92	96
	R35(31)		93	94
	R35(40)		92	98
	R35(A1)		61	65
	R35(A2)		59	51
	TW1		59	57
	PCP		71	77
		Mean	78	80
Scott AFB, IL	A9B1		47	33
	A9B2		65	72
	A9B3		65	62
	A3B		56	54
		Mean	58	56
		Overall Mean	70	70

TABLE 15. SUMMARY OF CONDITION RESULTS FROM ADDITIONAL TESTS FOR JOINTED CONCRETE PAVEMENTS

Pavement Location	Pavement Feature	Mean Subjective PCR	Calculated PCI
George AFB, CA	TW3	78	73
	TW2	18	23
	TW5C	61	55
	Mean	52	50
Elmendorf AFB, AK	A1(#1)	93	90
	A1(East)	30	27
	TW8	7	5
	Mean	43	41
Eielson AFB, AK	Refuel Pad	86	80
Fort Wainwright, AK	RW#1	23	21
	#2	27	26
	#3	56	58
	Mean	35	35
	Overall Mean	48	46

between the highest and lowest rater for each of these 10 sections is 14.4 points, illustrating the high variability in opinion from one rater to another even though all four raters were experienced pavement engineers. Figure 23 presents a plot which shows similar results from each airfield. The mean absolute difference is generally much lower than the mean range between raters. The mean of the four subjective ratings for each section ($\overline{PCR}$) is a much less variable rating which therefore reasonably estimates the condition of the pavement. Table 16 summarizes all subjective ratings.

Figure 24 shows the correlation between PCI and $\overline{PCR}$ for all 40 sections. Analysis of the data resulted in the following statistics:

1. The correlation coefficient between the PCI and $\overline{PCR}$ is 0.97.

2. The mean PCI for all sections is 63.8.

3. The mean $\overline{PCR}$ for all sections is 64.7.

4. The mean difference between the PCI and $\overline{PCR}$ for all sections is -0.9.

5. The standard deviation of the differences between the PCI and $\overline{PCR}$ is 5.73.

Assuming that the differences between the PCI and $\overline{PCR}$ are normally distributed, the confidence interval on the differences can be calculated as

$$\pm K \frac{5.73}{\sqrt{n}}$$

where K = value from normal tables based on confidence level (K = 1.96 for 95 percent confidence), and
n = number of sample units surveyed in the pavement feature.

For example, if five sample units were surveyed and the PCIs of the samples were averaged to determine the PCI of the pavement feature, the 95 percent confidence interval or the difference between the PCI and $\overline{PCR}$ of the feature would be

$$\pm 1.96 \frac{5.73}{\sqrt{5}} = -5 \text{ to } +5$$

i.e., there is 95 percent confidence that the PCI of the feature is within ± 5 of the average condition rating, $\overline{PCR}$, that would have been determined by a group of experienced pavement engineers. Thus, the final PCI procedure is a reliable pavement condition rating technique. The resulting PCI and its corresponding rating ("good," "poor," etc.) can be very significant in determining maintenance and repair needs, as discussed in Section VIII.

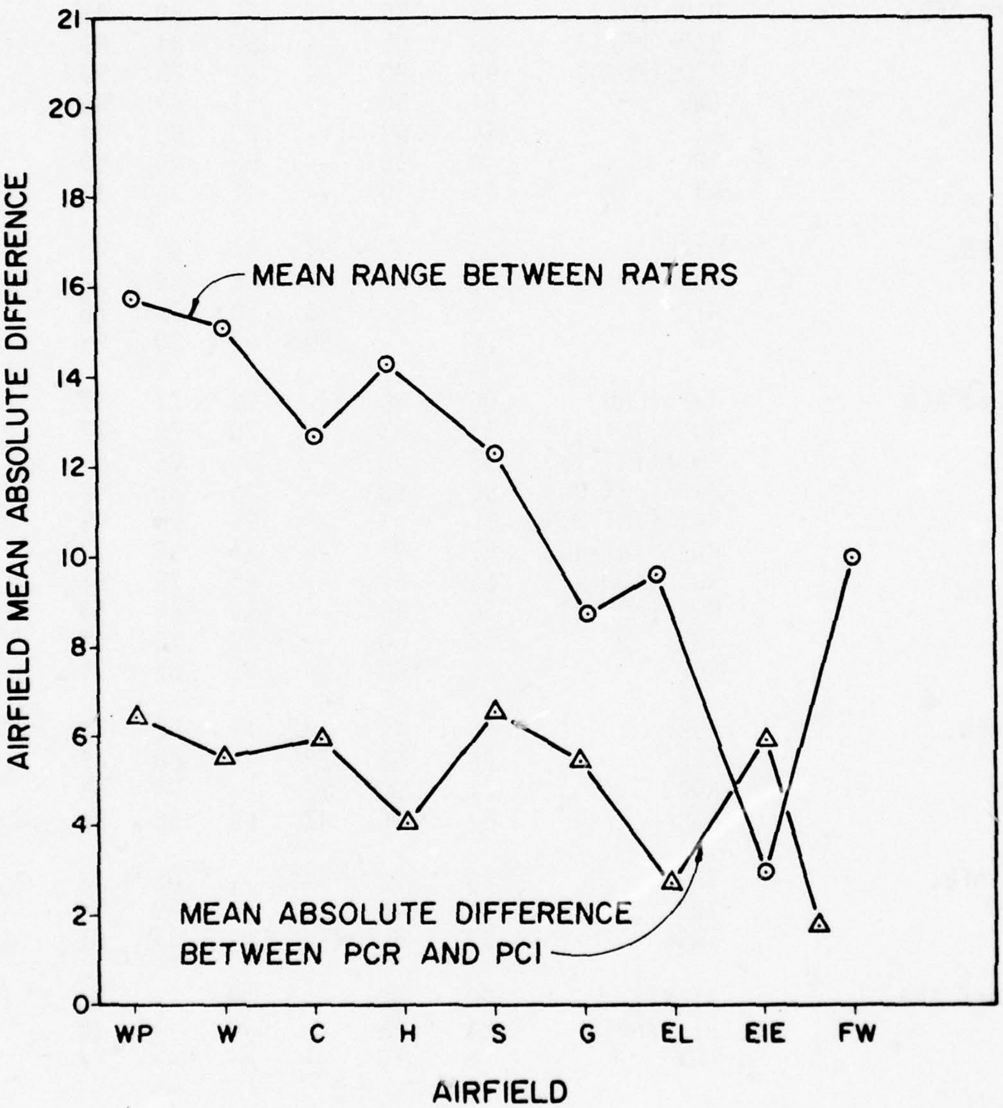


Figure 23. Comparison Between the Mean Range Between Raters and the Mean Absolute Difference Between $\overline{PCR}$ and PCI.

TABLE 16. INDIVIDUAL RATINGS FOR EACH JOINTED CONCRETE PAVEMENT FEATURE

Pavement Location	Pavement Feature	Raters[a] C1	C2	C3	B1	B2	PCR
Wright-Patterson AFB, OH	R6B	77	90	--	88	85	85
	R10D	63	67	--	56	85	68
	T7C	35	40	--	45	42	41
	T2A	75	81	--	83	80	80
	A14B	80	71	--	85	90	81
Williams AFB, AZ	R30L(9/1)	35	30	--	56	60	45
	R30R(MR/1)	88	95	--	90	84	89
	R30L(M6/4)	95	90	--	--	85	90
	TW6	54	50	--	51	41	49
	A1	64	62	--	69	60	64
	A2	44	50	--	62	45	50
	A3	41	30	--	41	38	37
Craig AFB, AL	R14L	98	--	94	84	95	93
	R32L	53	--	47	65	65	57
	A1	75	--	73	80	78	76
	A2	78	--	80	90	90	85
Homestead AFB FL	RW35(END)	95	90	--	95	77	89
	RW35(INT 1)	83	83	--	70	70	77
	RW35(INT 13)	95	90	--	95	85	91
	RW35(INT 20)	96	90	--	95	85	92
	RW35(INT 31)	95	93	--	95	90	93
	RW35(INT 40)	97	95	--	85	90	92
	RW35(ADD 1)	65	62	--	45	70	61
	RW35(ADD 2)	56	60	--	55	65	59
	TW1	58	60	--	50	70	59
	PCP	75	62	--	82	65	71
Scott AFB, IL	A9B1	50	42	48	--	50	47
	A9B2	66	62	72	--	60	65
	A9B3	71	60	72	--	57	65
	A3B	61	55	47	60	56	56
George AFB, CA	TW3	76	72	--	--	85	78
	TW2	15	18	--	--	20	18
	TW5C	57	60	--	--	65	61
Elmendorf AFB, AK	A1(#1)	90	90	--	98	--	93
	A1 (EAST)	24	25	--	40	--	30
	TW8	5	10	--	--	--	7

TABLE 16. INDIVIDUAL RATINGS FOR EACH JOINTED CONCRETE PAVEMENT FEATURE (CONCLUDED)

Pavement Location	Pavement Feature	Raters[a] C1	C2	C3	B1	B2	$\overline{PCR}$
Eielson AFB, AK	Refuel Pad	88	85	--	85	--	86
Fort Wainwright,	RW#1	20	25	--	25	--	23
	#2	27	30	--	25	--	27
	#3	57	65	--	45	--	56

[a]C1, C2, C3 = CERL project staff engineers
B1 = major command pavement engineer
B2 = base pavement engineer or AFCEC pavement engineer

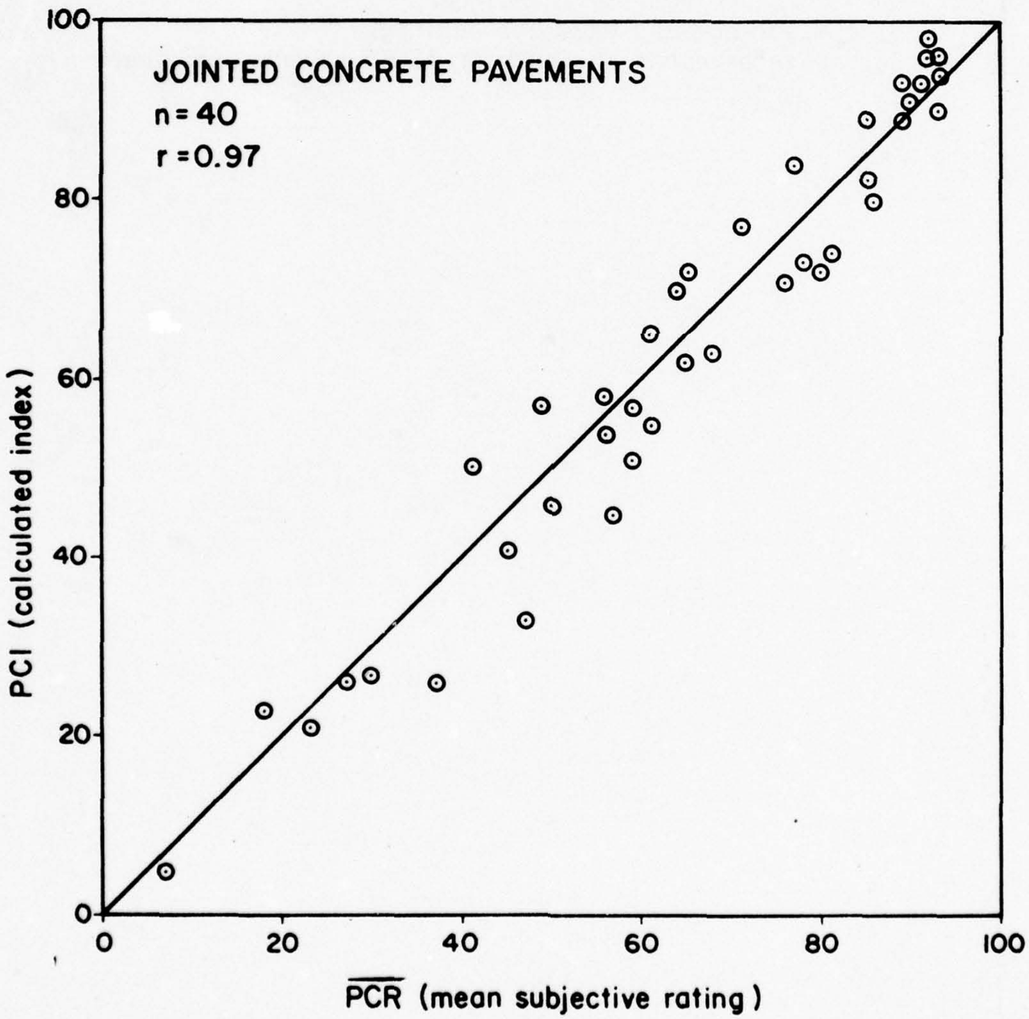


Figure 24. Correlation Between $\overline{PCR}$ and PCI for All Jointed Concrete Pavement Sections Surveyed.

SECTION VI

PAVEMENT CONDITION INDEX FOR ASPHALT- AND TAR-SURFACED PAVEMENTS

This section provides complete details of the development of the PCI for asphalt- and tar-surfaced pavements, including asphalt or tar surfacing over granular or stabilized base and over Portland cement concrete (i.e., an overlay). Field verification and other results are also provided. This developmental work required many months of trial testing, evaluation, and improvement to produce an acceptable procedure. Appendix A presents the overall procedure for field use.

DEVELOPMENT OF DISTRESS DEFINITIONS AND DEDUCT VALUE CURVES

Initial Definitions and Values

The first steps were (1) to review previous literature on asphalt pavement distresses[15,16,17,18] and condition survey reports conducted by the Navy from five airfields and (2) to observe airfield pavement condition firsthand (at Tinker AFB, OK). Based on these sources of information and the project staff's previous experience, an initial set of distresses was selected and severity levels were defined. Initial surveys and other information indicated that a "sample unit" of approximately 5000 square feet would provide an adequate area of pavement for evaluation and computation of the PCI; such sample units can be conveniently obtained by subdividing a large feature. The amount or density of distress was determined by measuring the surface area of distress (such as area of raveling) and dividing by the total area of the sample unit. One exception to this determination was for linear cracking (longitudinal or transverse), which was measured by length in feet; its density was expressed in feet/100 square feet. If the width was considered to be 1 foot, this procedure gave the same numerical results as if the linear crack were measured by "area." Hence a 150-foot-long crack in 5000 square feet section would give a density of

$$\frac{150}{5000} \times 100 = 3.0 \text{ percent}$$

[15] E. J. Barenberg, C. L. Bartholomew, and M. Herrin, *Pavement Distress Identification and Repair*, Technical Report P-61/AD758447 (CERL, March 1973).

[16] M. Y. Shahin, M. I. Darter, and F. M. Rozanski, *Pavement Inspection Reference Manual*, Technical Information Pamphlet C-48/ADA017329 (CERL, September 1975).

[17] *Standard Nomenclature and Definitions for Pavement Components and Deficiencies*, Special Report (Highway Research Board, 1970).

[18] M. I. Darter and E. J. Barenberg, *Zero Maintenance Pavement: Performance Capabilities and Requirements*, Preliminary Interim Report (University of Illinois, 1975).

The initial weighting deduct values were determined based on the limited experience gained thus far. A discrete method was used for density, rather than the continuous curve used for concrete pavements. For example, the density of alligator cracking was divided into three ranges: 0.1 to 3.9 percent, 4.0 to 10.9 percent, 11.0 to 100.0 percent. Weighting deduct values were assigned for each combination of severity level and density according to the subjective scale shown in Figure 16. Table 17 shows an example for alligator cracking.

TABLE 17. INITIAL WEIGHTING DEDUCT VALUES FOR ALLIGATOR CRACKING SEVERITY

Density	Low	Medium	High
Low (0.1 to 3.9 percent)	10	21	41
Medium (4.0 to 10.9 percent)	21	43	84
High (11.0 to 100 percent)	41	84	100

The PCI of the pavement sections was calculated using Equation 2 as for concrete pavements.

First Field Test, Evaluation, and Revision

A field test of the initial procedure was conducted on four asphalt-surfaced pavements at Wright-Patterson AFB, OH. Each section was surveyed, all distresses were recorded for each section, and a PCI was computed for each according to Equation 2. Four experienced pavement engineers (two CERL project staff members, the major command pavement engineer, and the base pavement engineer) subjectively rated each pavement section using the rating form in Figure 16. The rating criteria included pavement structural integrity and surface operational condition. The average of the four independent subjective pavement condition ratings ($\overline{PCR}$) was computed for each section.

Evaluation of the results obtained indicated two major deficiencies:

1. The definitions of several distress types and levels of severity did not describe actual conditions adequately.

2. The calculated PCI of two sections was reasonably close to the $\overline{PCR}$; however, two sections were considerably different.

The evaluation was limited by the fact that all the pavement sections were asphalt overlays over concrete. Certain distress types such as alligator or fatigue cracking therefore did not exist and could not be evaluated.

Based on this first field test, the procedures, including both distress definitions and deduct values, were extensively revised. Considerable analysis of the deduct values indicated that a continuous curve similar to that used for concrete would provide a more adequate result.

The deduct value curves were revised in the following manner for each distress type at a particular level of severity:

1. Three project staff engineers independently rated 50 x 100 feet pavement sections having varying amounts of distress according to the scale in Figure 16. Each rater gave the pavement section a subjective rating such as "excellent," "good," or "fair," and a numerical value within that rating.

2. The ratings were made for 4 to 5 levels of density (or amount). For example, alligator cracking was rated at density levels of 0.1, 1, 5, 20, and 50 percent.

3. The mean of the three subjective ratings ($\overline{PCR}$) was computed for each density level, and the mean deduct value ($\overline{DV}$) was computed as:

$$\overline{DV} = 100 - \overline{PCR}.$$

A plot of density of distress versus mean deduct value was developed, and a best fit smooth curve was fit through the points. Figure 25 illustrates these curves for alligator cracking.

This procedure was repeated for each of 16 distress types and one to three levels of severity for each type. The procedures were revised and prepared for additional field testing.

Second Field Test, Evaluation, and Revision

A field test of the revised procedures was conducted on 17 asphalt- or tar-surfaced pavement sections at Williams AFB, AZ, and Craig AFB, AL. Distress data were recorded according to the new definitions, and subjective ratings of each section were made by four experienced pavement engineers (two from the CERL project staff, the major command engineer, and the local base engineer). The PCI and the mean $\overline{PCR}$ were computed for each section. Evaluation of the results obtained indicated the following deficiencies:

1. Some of the definitions did not clearly describe existing distresses.

2. The PCIs for several sections containing several distress types were significantly less than the $\overline{PCR}$s.

Therefore, several of the distress definitions were revised to reflect the experience gained during the second field test. Further consideration and analysis of the discrepancy between PCI and $\overline{PCR}$ led to the conclusion that since the deduct value curves were derived for only one distress type, the deduct values cannot simply be added together when more than one distress type occurs in a pavement section. A correction factor must be applied so that the PCI will better predict the $\overline{PCR}$.

Analysis of the available data indicated that the total deduct value (i.e., the sum of all deducts in a section of pavement) must be

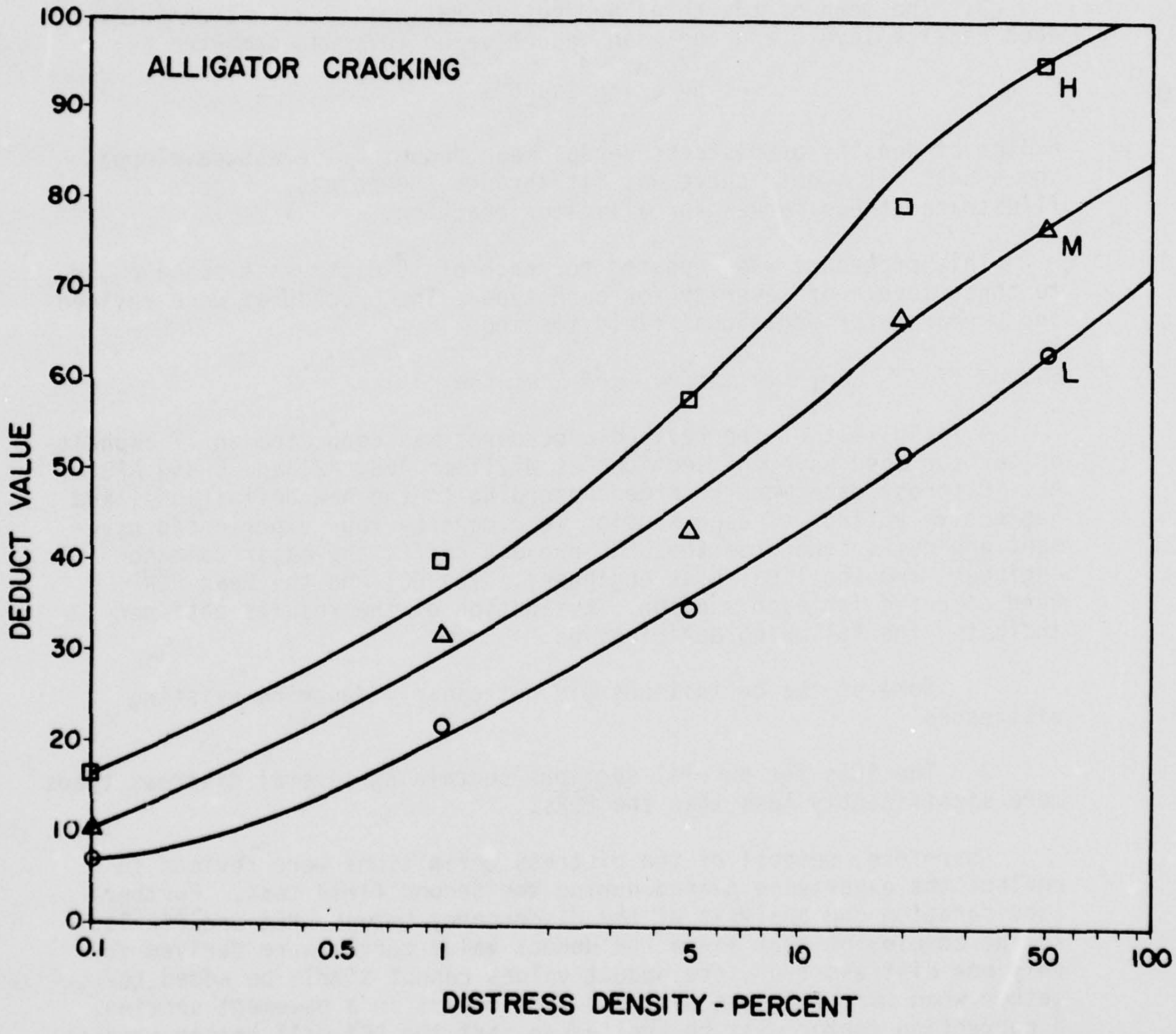


Figure 25. Example Showing Development of Deduct Value Curves for Alligator Cracking.

adjusted to reflect the number of deducts (or distress types plus levels of severity) and the magnitude of the total deduct value.

This adjustment function for multiple distresses was determined by subjectively rating many pavement sections containing from two to six distress types and/or levels of severity. The total sum of calculated deduct values determined using the individual deduct value curves and the corrected deduct value determined by subtracting the $\overline{PCR}$ from 100 for each section were then plotted.

Figure 26 shows an example of plot of these variables for a section where q=3 (q is the number of distress types at specific levels of severity with deduct values exceeding 5). The reason for only counting deduct values greater than 5 is that the data show that smaller deducts have little effect on pavement condition. For example, a pavement might have six distresses that were mostly very minor; therefore, the correction curve for q=6 would give too large an adjustment. Table 18 presents data for an example pavement section.

TABLE 18. EXAMPLE ASPHALT- OR TAR-SURFACED PAVEMENT DATA

Distress	Density	Deduct Value
Alligator Cracking light severity	2 percent	27
Linear Cracking		
light severity	4 feet/100 square feet or 4 percent	12
medium severity	1 percent	11
Raveling light	2 percent	4
Patching light	2 percent	5
	Total deduct value =	59
	q = number of deducts>5 = 3	

The mean $\overline{PCR}$ of this section is 67, and hence the corrected deduct value is 33 (100-67 = 33). This result indicates that the total deduct value of 59 shown in the table is too large and must be adjusted toward 33. Figure 26 plots data for 17 sections where q=3. All the data points lie below the line of equality and the amount below increases as the total sum of calculated deduct value increases.

This analysis was repeated for q=2, 4, and 6; the results show that the curves shift as the q increases (Figure 7). The correction curves shown in Figure 27 were used in all subsequent ratings and significantly improved the estimation of pavement condition.

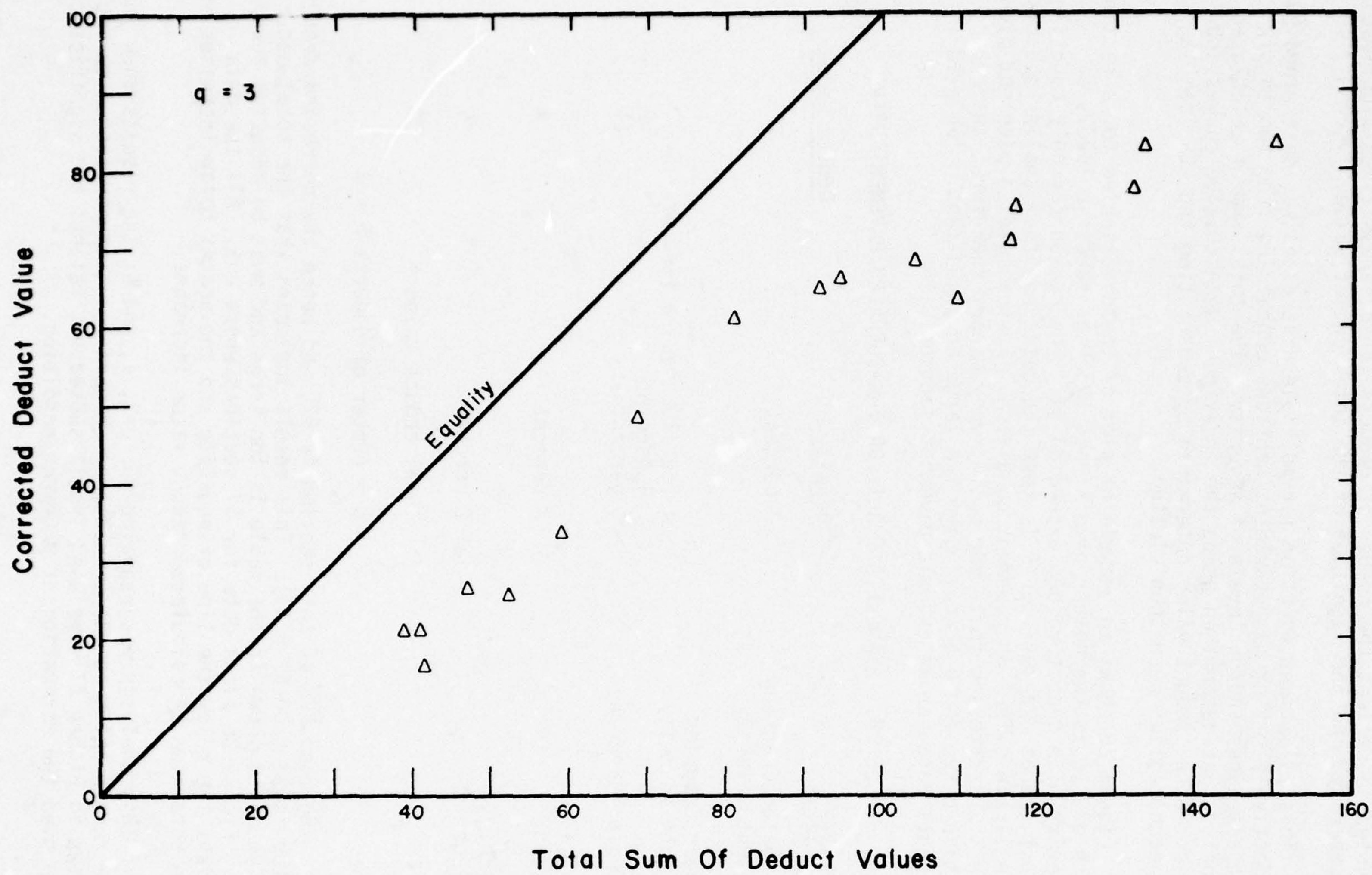


Figure 26. Example Correction Curves for Multiple Distress Types for Asphalt- or Tar-Surfaced Pavements.

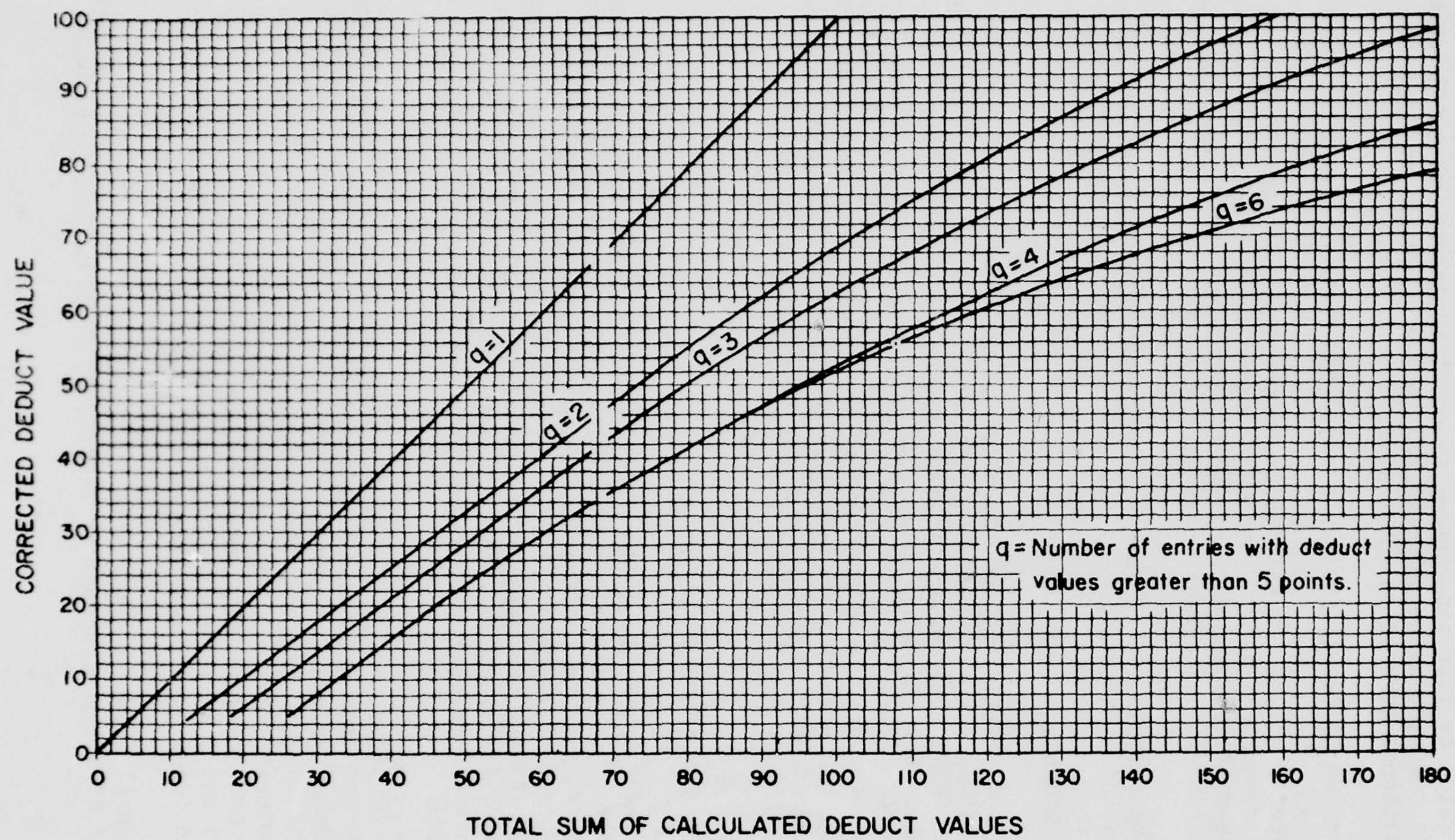


Figure 27. Corrected Deduct Value Curves for Asphalt- or Tar-Surfaced Pavements.

Third Field Test, Evaluation, and Revision

A third field test was conducted on 17 pavement sections at Homestead AFB, FL, and Scott AFB, IL. The sections were surveyed and subjectively rated by four experienced pavement engineers. The PCI of each section was computed using the revised procedure, which included the multiple distress correction curves.

Evaluation of results obtained indicated the following:

1. Nearly all of the distresses observed at the two Air Force bases were adequately defined by the existing definitions. A few were found to be deficient and were revised (particularly alligator cracking, which occurred extensively at these airfields).

2. The calculated PCI values corresponded closely with the mean PCR ratings for each section. A few of the deduct value curves, however, required revision. The multiple distress curves definitely improved the procedure significantly.

Figure 28 illustrates the improvements made in distress definitions. Longitudinal and transverse cracking, which is described in the figure, was found at every airfield surveyed. The initial and final definitions differed considerably. Similar improvements were made to other distress definitions. Obtaining clear and complete descriptions of distress is essential to the success of the pavement condition rating procedure so that existing distress can be correctly identified. Also, correct deduct values cannot be assigned unless the distress is adequately identified and defined.

ILLUSTRATION OF DEDUCT VALUE CURVES

The deduct value curves for the 16 distress types differ considerably. Figure 29 illustrates the effect of different distress types (for a medium severity level for example) on deduct values. Most of the curves have similar shapes, but their effects on the PCI differ greatly. Alligator or fatigue cracking has a much larger deduct value than does block cracking for example. Table 19 shows the PCI values obtained for a section with 10 percent having the indicated distress at a medium severity level.

Figure 30 shows typical differences between levels of severity for longitudinal and transverse cracking (defined in Figure 28). Table 20 shows the deduct values and general ratings obtained for a pavement section containing 10 feet/100 square feet or 10 percent cracking of different severity levels. The results in Table 20 show that a section of asphalt- or tar-surfaced pavement having 10 feet/100 square feet of longitudinal and transverse cracking has a PCI of 46 to 76 and a rating of "fair" to "very good" depending on the severity of the cracks.

The general shape of the curves is significant because it indicates the relative effect that amount or density of distress has on pavement

INITIAL

Name of Distress: Longitudinal and Transverse Cracking (Non-PCC Joint Reflection)

Description: Longitudinal cracks are parallel to the pavement's centerline and usually run along the wheel path. Transverse cracks extend across the pavement at approximately right angles to the pavement eye. If the pavement is fragmented along a crack, the crack is said to be spalled. Longitudinal cracks can be an early sign of alligator cracking, lane joint cracking, or reflective cracking from a PCC base. Transverse cracks are caused by low temperature shrinkage of reflection from a PCC base.

Severity Levels: H - Crack is severely spalled and/or averages 1 in. or more in width.

M - Crack is slightly to moderately spalled and/or averages less than 1 in. wide.

L - Hairline crack with no spalling (1/4 in. wide)

FINAL

Name of Distress: Longitudinal and Transverse Cracking (Non-PCC Joint Reflective)

Description: Longitudinal cracks are parallel to the pavement's centerline or laydown direction. They may be caused by (1) a poorly constructed paving lane joint, (2) shrinkage of the AC surface due to low temperatures or hardening of the asphalt, or (3) a reflective crack caused by cracks beneath the surface course, including cracks in PCC slabs (but not at PCC joints). Transverse cracks extend across the pavement at approximately right angles to the pavement centerline or direction of laydown. They may be caused by items 2 or 3 above. These types of cracks are not usually load associated. If the pavement is fragmented along a crack, the crack is said to be spalled.

Severity Levels: L - Cracks have either minor spalling (little or no FOD potential) or no spalling. The

Figure 28. Initial and Final Description of Longitudinal and Transverse Cracking.

cracks can be filled or nonfilled. Non-filled cracks have a mean width of 1/4 in. or less; filled cracks are of any width, but their filler material is in satisfactory condition.

M - One of the following conditions exists: (1) cracks are moderately spalled (some FOD potential) and can be either filled or nonfilled of any width; (2) filled cracks are not spalled or are only lightly spalled, but the filler is in unsatisfactory condition; (3) nonfilled cracks are not spalled or are only lightly spalled, but mean crack width is greater than 1/4 in.; or (4) light random cracking exists near the crack or at the corners of intersecting cracks.

H - Cracks are severely spalled, causing definite FOD potential. They can be either filled or nonfilled of any width.

How to Measure: Longitudinal and transverse cracks are measured in lineal feet. The length and severity of each crack should be identified and recorded. If the crack does not have the same severity level along its entire length, each portion of the crack having a different severity level should be recorded separately. For an example, see Joint Reflection Cracking.

Figure 28. Initial and Final Description of Longitudinal and Transverse Cracking (concluded).

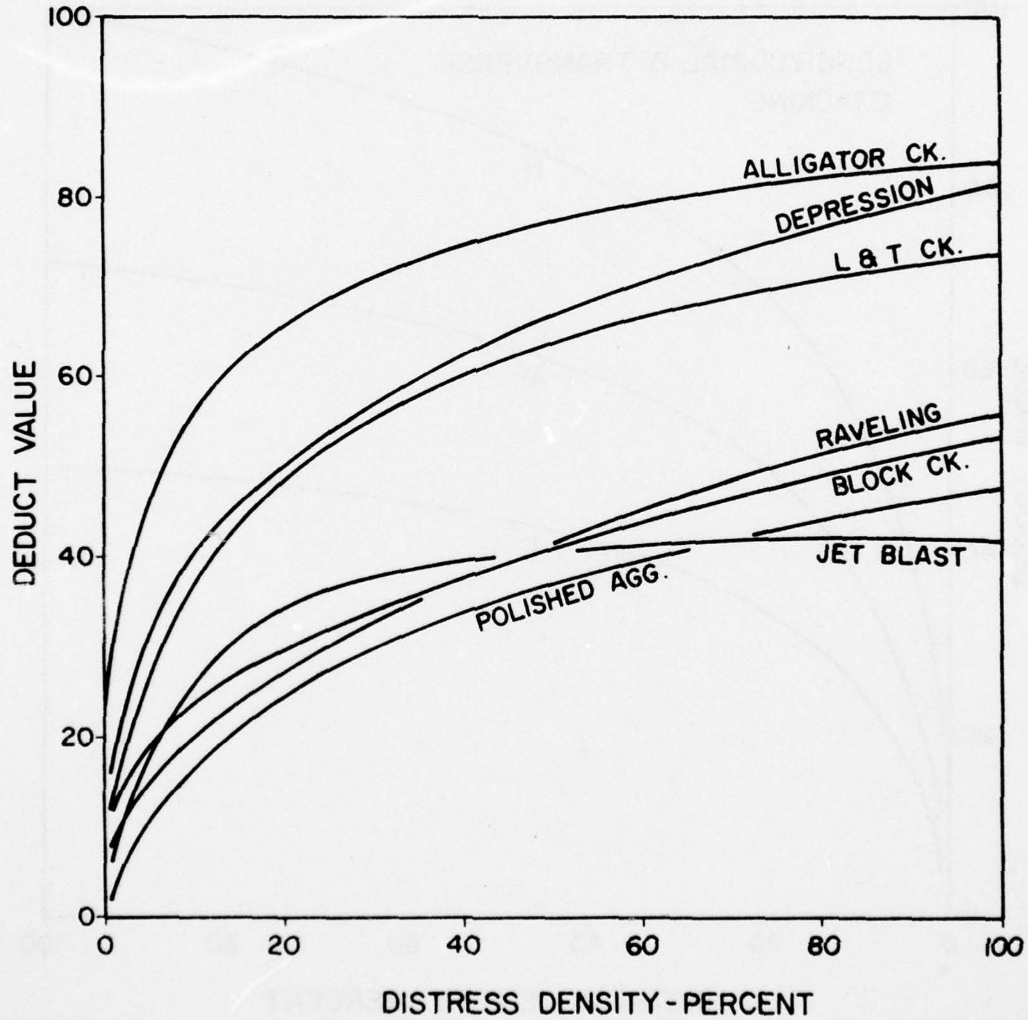


Figure 29. Illustration of Deduct Value Curves for Several Distress Types, All Distresses at Medium Severity Level.

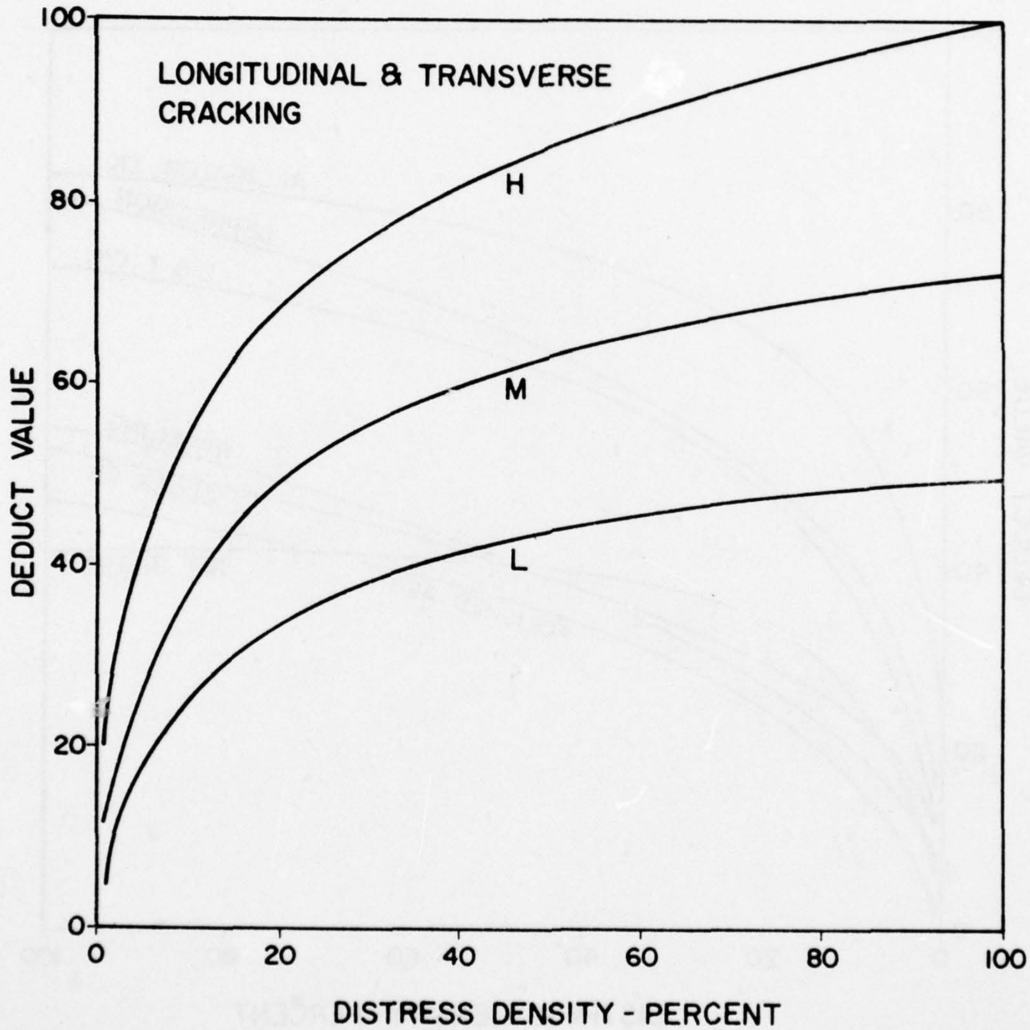


Figure 30. Example Deduct Value Curves for Three Severity Levels of Longitudinal and Transverse Cracking.

TABLE 19. PCI VALUES FOR DIFFERENT DISTRESS TYPES IN ASPHALT- OR TAR-SURFACED PAVEMENT

Distress	Deduct Value	PCI	General Condition
Polished Aggregate	16	84	Very Good
Block Cracking	24	76	Very Good
Depression	40	60	Good
Longitudinal and Transverse Cracking	37	63	Good
Alligator Cracking	56	44	Fair

TABLE 20. DEDUCT VALUES FOR DIFFERENT LEVELS OF SEVERITY OF LONGITUDINAL AND TRANSVERSE CRACKING

Severity	Deduct Value	PCI	Rating
Low	24	76	Very Good
Medium	37	63	Good
High	54	46	Fair

condition. The deducts increase rapidly up to about 20 percent area and then level off. Hence the initial development of linear cracking in asphalt pavement has a very significant impact on a pavement's condition.

EXAMPLE CALCULATION OF PCI

This section illustrates the calculation of the PCI for a 50-foot-wide taxiway at Homestead AFB, FL. To determine the section's PCI, a sample unit of the taxiway 50 feet wide by 100 feet long is surveyed. The amounts of each of the four distress types found are summarized on the field condition data sheet used for asphalt- and tar-surfaced pavements (Figure 31). For example, 594 square feet of alligator cracking (No. 1) were found in the section: four areas of 90 feet x 3 feet = 270 square feet, 90 feet x 3 feet = 270 square feet, 15 feet x 2 feet = 30 square feet, and 12 feet x 2 feet = 24 square feet. Its density is calculated as (594/5000) 100 = 11.88 percent. The deduct values for each distress are determined from curves presented in Appendix A, Figure A-9. The total deduct of 81 is adjusted to 56 using the curve in Figure 27 for q=2, since two deduct values are greater than 5. The PCI is then calculated to be 44, which indicates a "fair" rating. The subjective ratings for this section were 42, 50, 50, and 50 for a mean $\overline{PCR}$ of 48.

ASPHALT OR TAR SURFACED PAVEMENT
CONDITION SURVEY DATA SHEET FOR SAMPLE UNIT

AIRFIELD Homestead AFB FEATURE Par. Taxiway

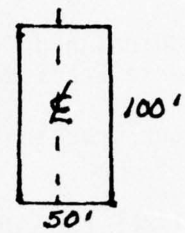
DATE 3/28/76 SAMPLE UNIT 7

SURVEYED BY MD/MS AREA OF SAMPLE 5000 sq ft

Distress Types

1. Alligator Cracking
2. Bleeding
3. Block Cracking
4. Corrugation
5. Depression
6. Jet Blast
7. Jt. Reflection (PCC)
8. Long. & Trans. Cracking
9. Oil Spillage
10. Patching
11. Polished Aggregate
12. Raveling/Weathering
13. Rutting
14. Shoving from PCC
15. Slippage Cracking
16. Swell

SKETCH:



EXISTING DISTRESS TYPES

	1	8	12	13		
	90x3 L	10 L	10x4 L	90x3 L		
	90x3 L	25 L		90x3 L		
	15x2 L					
	12x2 L					
TOTAL SEVERITY L	594 sq ft	35 ft	40 sq ft	540 sq ft		
TOTAL SEVERITY M						
TOTAL SEVERITY H						

PCI CALCULATION

DISTRESS TYPE	DENSITY	SEVERITY	DEDUCT VALUE
1	11.88	L	45
8	0.70	L	5
12	0.80	L	2
13	10.80	L	29
DEDUCT TOTAL q = 2			81
CORRECTED DEDUCT VALUE (CDV)			56

PCI = 100 - CDV = 44

RATING = Fair

Figure 31. Condition Survey Data Sheet for Example Calculation of PCI.

EVALUATION AND FIELD VERIFICATION

Evaluation

An evaluation of the pavement condition rating procedure was conducted using results from all 38 sections at the five airfields. The PCI of each of the 38 sections was computed using the final procedure, and these results were compared with the subjective ratings (PCR) of experienced pavement engineers. Table 21 summarizes these data. Results showed that:

1. The mean PCR and PCI sections at each of the airfields compare very closely, with the overall mean showing only one point difference.

2. The mean absolute difference between the PCR and PCI for all sections is relatively small at 4.8 points. The differences range from 0 to 21 points.

Field Validation

Although the results from the 38 sections provided strong field verification of the procedure and the calculated PCIs appeared to predict closely the mean subjective opinion of experienced pavement engineers, additional tests were believed to be necessary to test the procedure with data other than that from which it was developed.

Three additional airfields (George AFB, CA, Elmendorf AFB, AK, and Eilson AFB, AK) were visited and 35 asphalt- and tar-surfaced pavement sections were surveyed.

Table 22 summarizes the results obtained from these bases. The mean absolute difference between the $\overline{PCR}$ and the calculated PCI is 3.4 points, which is less than the 4.8 for the original 38 sections. The differences range from 0 to 14 points. The overall mean $\overline{PCR}$ of all the sections is 54 and the mean PCI is 56.

The $\overline{PCR}$ was subjectively rated by two project staff members from CERL and the base or major command pavement engineers for the base surveyed. A few deficiencies in distress definitions and deduct curves were identified and corrected.

The differences between $\overline{PCR}$ and PCI can be compared to the range of differences between the individual raters for each airfield. For example, at Homestead AFB, the mean absolute difference between the $\overline{PCR}$ and the PCI is 3.8 points for nine sections. However, the mean range between the highest and lowest rater for each of these nine sections is 12.2 points, illustrating the high variability in opinion from one rater to another, even though all four raters were experienced pavement engineers. Figure 32 presents a plot which shows similar results from each airfield. The mean absolute difference is generally much lower than the mean range between raters. Table 23 summarizes all the subjective ratings.

TABLE 21. SUMMARY OF PCI AND $\overline{PCR}$ DATA FROM FIELD SURVEYS FOR ASPHALT- AND TAR-SURFACED PAVEMENTS

Pavement Location	Pavement Feature	$\overline{PCR}$	Calculated PCI
Wright-Patterson AFB, OH	R3C	87	82
	T12B	65	71
	T23B	48	41
	T24B	71	75
	Mean	68	68
Williams AFB, AZ	TW4	62	70
	R30C (end)	42	49
	R30C (M 2/7)	93	100
	R30R (M 7/2)	84	86
	TW6	57	78
	RW (coolidge #1)	53	57
	RW (coolidge #2)	48	57
	Mean	63	71
Craig AFB, AL	R14L (M44)	80	81
	R14L (M62)	86	90
	TW3B (#1)	88	88
	TW3B (#2)	84	79
	TW3B (#3)	84	89
	TW3B (#4)	81	82
	TW3B (#5)	85	84
	RW1	78	81
	RW (s. end)	83	79
	TW7	78	80
	Mean	83	83
Homestead AFB, FL	TW (Par #7)	48	46
	TW (Par #14)	48	43
	TW (Par #33)	71	73
	TW (Par #46)	61	55
	TW (Par add 1)	40	42
	TR6	50	53
	TR9	48	46
	TWA4	75	80
	TW (old)	25	18
	Mean	52	51
Scott AFB, IL	R3c (#1)	56	64
	R4c (#1)	51	51
	R4c (#2)	51	54
	TW (s. #1)	42	36
	TW (s. #2)	29	22
	A (s. #3)	69	72
	TWF	69	79
	T 13 B(#20,21,22)	69	72
	Mean	55	56
	Overall Mean	64	66

TABLE 22. SUMMARY OF RESULTS FROM ADDITIONAL TESTS FOR ASPHALT- AND TAR-SURFACED PAVEMENTS

Pavement Location	Pavement Feature	Mean PCR	Calculated PCI
George AFB, CA	TW6 #1	46	42
	#2	34	33
	#3	49	53
	#4	29	39
	#5	22	23
	#6	26	25
	#7	37	36
	#8	37	38
	#9	49	35
	#10 (before repair)	27	25
	#10 (after repair)	54	52
	#11	34	32
	Mean	37	36
Elmendorf AFB, AK	RW #1	70	71
	#2	71	78
	#3	75	82
	#4	76	77
	#5	74	72
	#6	79	80
	#7	79	78
	A1	82	83
	A2	53	64
	TW1	62	66
	TW2	67	65
	TW3	68	66
	Mean	71	73
Eielson AFB, AK	RW #1	63	65
	#2	64	61
	#3	66	68
	#4	71	71
	#5	68	65
	#6	64	65
	#7	58	66
	#8	62	65
	#9	56	48
	TW6 #1	28	26
	TW6 #2	56	63
	Mean	60	60
	Overall Mean	56	57

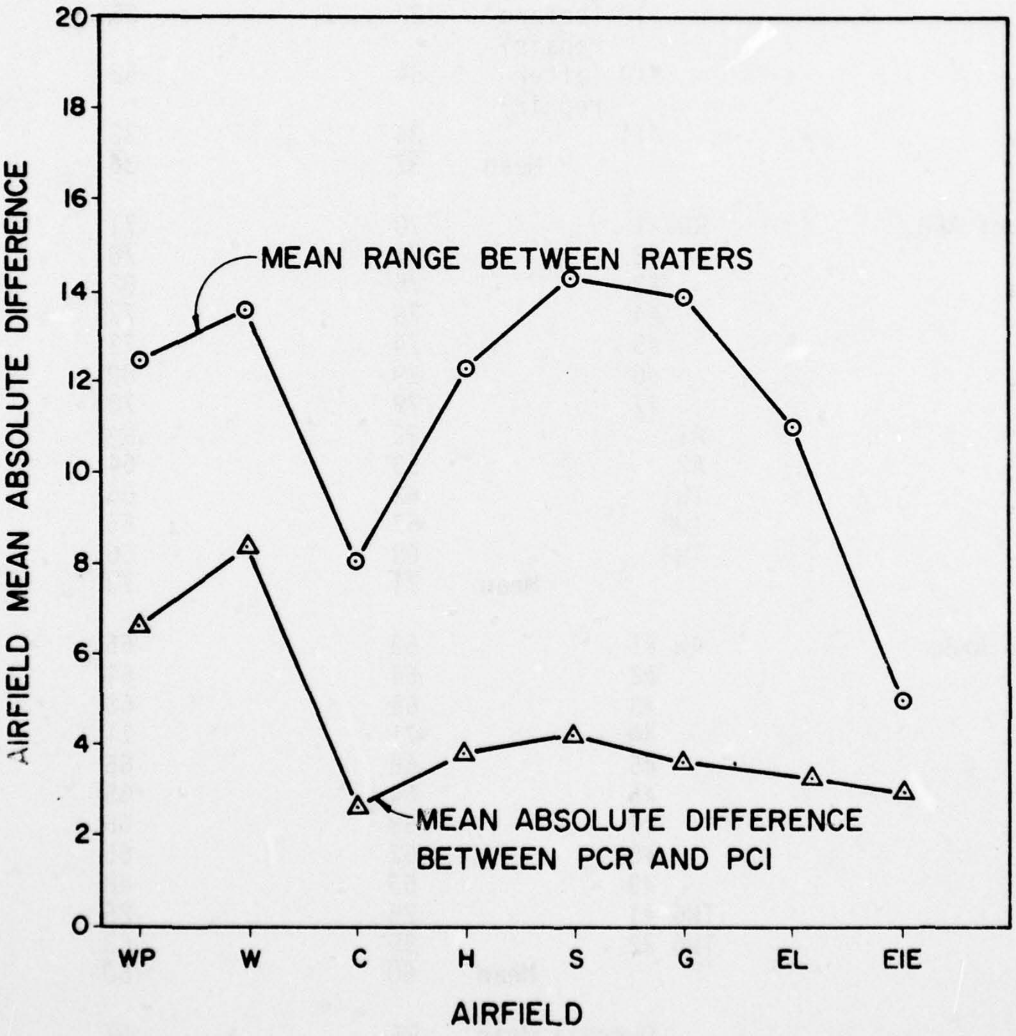


Figure 32. Comparison Between the Mean Range Between Raters and the Mean Absolute Difference Between $\overline{PCR}$ and PCI.

TABLE 23. INDIVIDUAL RATINGS FOR EACH PAVEMENT FEATURE SURVEYED FOR ASPHALT- OR TAR-SURFACED PAVEMENT

Pavement Location	Pavement Feature	C1	C2	C3	B1	B2	PCR
		Raters[a]					
Wright-Patterson AFB, OH	R3C	90	84	-	90	85	87
	T12B	65	69	-	59	65	65
	T23B	52	37	-	47	55	48
	T24B	78	62	-	65	81	71
Williams AFB, AZ	TW4	67	65	-	60	54	62
	R30C (end)	41	41	-	60	25	42
	R30C (M2/7)	95	95	-	90	90	93
	R30R (M7/2)	85	82	-	90	80	84
	TW6	57	50	-	65	56	57
	RW (coolidge #1	54	54	-	50	54	53
	RW (coolidge #2	48	42	-	45	57	48
Craig AFB, AL	R14L (M44)	73	-	80	80	85	80
	R14L (M62)	80	-	87	95	80	86
	TW3B (#1)	90	-	90	84	90	88
	TW3B (#2)	83	-	83	84	85	84
	TW3B (#3)	83	-	83	84	85	84
	TW3B (#4)	82	-	82	78	83	81
	TW3B (#5)	83	-	80	90	88	85
	RW1	73	-	75	80	83	78
	RW9 (s. end)	80	-	80	86	85	83
	TW7	70	-	80	80	80	78
Homestead AFB, FL	TW (Par #7)	50	42	-	50	50	48
	TW (Par #14)	49	48	-	50	45	48
	TW (Par #33)	70	75	-	62	75	71
	TW (Par #46)	61	56	-	66	60	61
	TW (Par addl)	38	38	-	40	45	40
	TR6	53	47	-	48	50	50
	TR9	50	35	-	53	56	48
	TWA4	71	70	-	-	85	75
	TW (old)	21	25	-	15	40	25
Scott AFB, IL	R3C (#1)	60	57	53	53	54	56
	R4C (#1)	50	47	52	58	47	51
	R4C (#2)	50	47	52	58	47	51
	TW (s. #1)	44	50	48	30	40	42
	TW (s. #2)	30	24	38	25	28	29
	A (s. #3)	69	70	60	-	75	69
	TW F	63	62	71	-	80	69
	T13B	68	62	70	66	80	72

TABLE 23. INDIVIDUAL RATINGS FOR EACH PAVEMENT FEATURE SURVEYED FOR ASPHALT- OR TAR-SURFACED PAVEMENT (CONCLUDED)

Pavement Location	Pavement Feature	C1	C2	C3	B1	B2	PCR
George AFB, CA	TW6 #1	42	47	-	-	50	46
	#2	37	40	-	-	25	34
	#3	50	47	-	-	50	49
	#4	38	30	-	-	20	29
	#5	25	30	-	-	10	22
	#6	26	40	-	-	12	26
	#7	39	26	-	-	50	38
	#8	32	38	-	-	40	37
	#9	46	45	-	-	55	49
	#10 (before repair)	25	20	-	-	35	27
	#10 (after repair)	56	45	-	-	60	54
	#11	35	32	-	-	35	34
Elmendorf AFB, AK	RW#1	70	70	-	70	-	70
	#2	70	78	-	65	-	71
	#3	75	82	-	68	-	75
	#4	73	80	-	75	-	76
	#5	72	71	-	80	-	74
	#6	76	82	-	80	-	79
	#7	76	82	-	80	-	79
	A1	93	87	-	65	-	82
	A2	64	55	-	40	-	53
	TW8 #1	55	60	-	70	-	62
	#2	67	65	-	70	-	67
	#3	68	70	-	65	-	68
Eielson AFB, AK	TW #1	63	60	-	65	-	63
	#2	65	62	-	66	-	64
	#3	65	70	-	62	-	66
	#4	72	75	-	66	-	71
	#5	68	70	-	65	-	68
	#6	63	70	-	60	-	64
	#7	60	55	-	58	-	58
	#8	65	62	-	60	-	62
	#9	57	55	-	55	-	56
	TW6#1	28	29	-	-	-	28
	#2	55	56	-	-	-	56

[a]C1, C2, C3 = CERL project staff engineers
B1 = major command pavement engineer
B2 = base pavement engineer or AFCEC pavement engineer

Figure 33 shows the correlation between PCI and $\overline{PCR}$ for all 73 sections. Analysis of the data resulted in the following statistics:

1. The correlation coefficient between the PCI and $\overline{PCR}$ is 0.96.

2. The mean PCI for all sections is 61.2.

3. The mean $\overline{PCR}$ for all sections is 60.2.

4. The mean difference between the PCI and $\overline{PCR}$ for all sections is +1.0.

5. The standard deviation of the differences between the PCI and $\overline{PCR}$ is 5.42.

Assuming that the differences between the PCI and $\overline{PCR}$ are normally distributed, the confidence interval on the differences can be calculated as

$$\pm K \frac{5.42}{\sqrt{n}}$$

where K = value from normal tables based on confidence level (K = 1.96 for 95 percent confidence), and
n = number of sample units surveyed in the pavement feature.

For example, if five sample units were surveyed and the PCIs of the samples were averaged to determine the PCI of the pavement feature, the 95 percent confidence interval or the difference between the PCI and $\overline{PCR}$ of the feature would be

$$\pm 1.96 \frac{5.42}{\sqrt{5}} = -4.75 \text{ to } +4.75$$

i.e., there is 95 percent confidence that the PCI of the feature is within ± 4.75 of the average condition rating, $\overline{PCR}$, that would have been determined by a group of experienced pavement engineers. Therefore, the final PCI procedure is a reliable pavement condition rating technique. The resulting PCI and its corresponding rating ("good," "poor," etc.) can be very significant in determining maintenance and repair needs, as discussed in Section VIII.

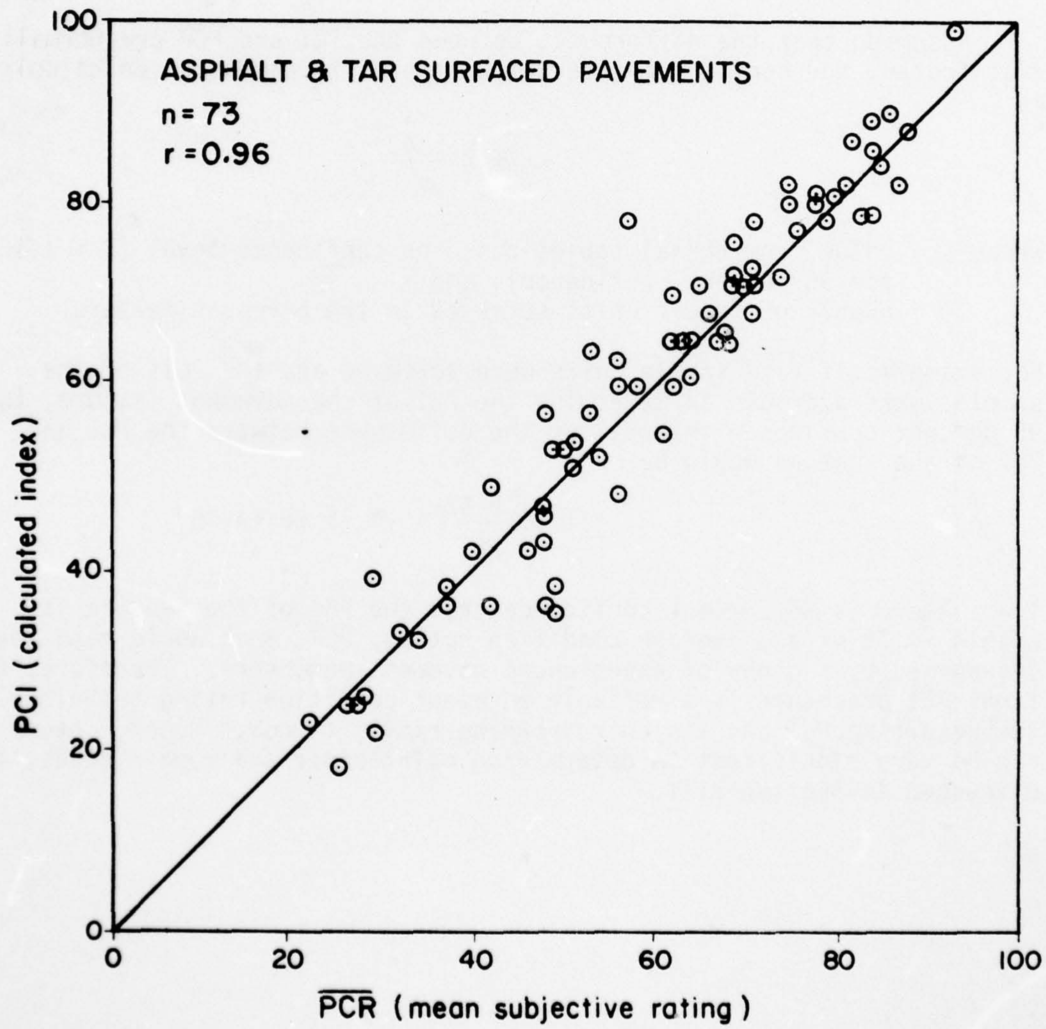


Figure 33. Correlation Between $\overline{PCR}$ and PCI for All Asphalt- or Tar-Surfaced Pavement Sections Surveyed.

SECTION VII

PAVEMENT INSPECTION

INTRODUCTION

Determination of the pavement condition index requires measurement of all distress existing on the pavement surface. A thorough pavement inspection must be made to determine the types, severity, and amounts (density) of distress present. The pavement inspection must be carefully organized and planned to provide the necessary information for determining the airfield pavement's condition.

This section presents guidelines for inspecting jointed concrete and asphalt- or tar-surfaced pavements. It also provides a procedure for sampling when time does not permit inspection of the entire pavement area. Equipment needed includes a measuring wheel (odometer), 12-inch measurement scale, and a 10-foot straightedge.

JOINTED CONCRETE PAVEMENT INSPECTION

The pavement must first be divided into features based on the pavement's design, construction history, and traffic area. A pavement feature should therefore (1) have consistent structural thickness and materials, (2) have been constructed at one time, and (3) be located in one traffic area. Condition of the pavement (based on observable distress) is an additional consideration for feature determination. These defined features should be outlined and identified on the airfield layout plan, as illustrated in Figure 34.

Inspection of an individual feature begins with dividing the feature into "sample units" of approximately 20 slabs (Figure 35). There are several reasons for dividing the feature into sample units of approximately 20 slabs:

1. The deduct value curves for each distress were developed based on a 20-slab pavement section.

2. The corrected deduct value curves used with multiple distresses were also based on a 20-slab pavement section.

3. The field validation indicated that this size section is convenient to inspect and rate.

4. Determination of a meaningful "percent slabs distressed" density rating for each distress type requires a total of at least 20 slabs.

AD-A048 884 CONSTRUCTION ENGINEERING RESEARCH LAB (ARMY) CHAMPAI--ETC F/G 1/5
DEVELOPMENT OF A PAVEMENT MAINTENANCE MANAGEMENT SYSTEM. VOLUME--ETC(U)
DEC 77 M Y SHAHIN, M I DARTER, S D KOHN MIPR-FQ8952-76-66005

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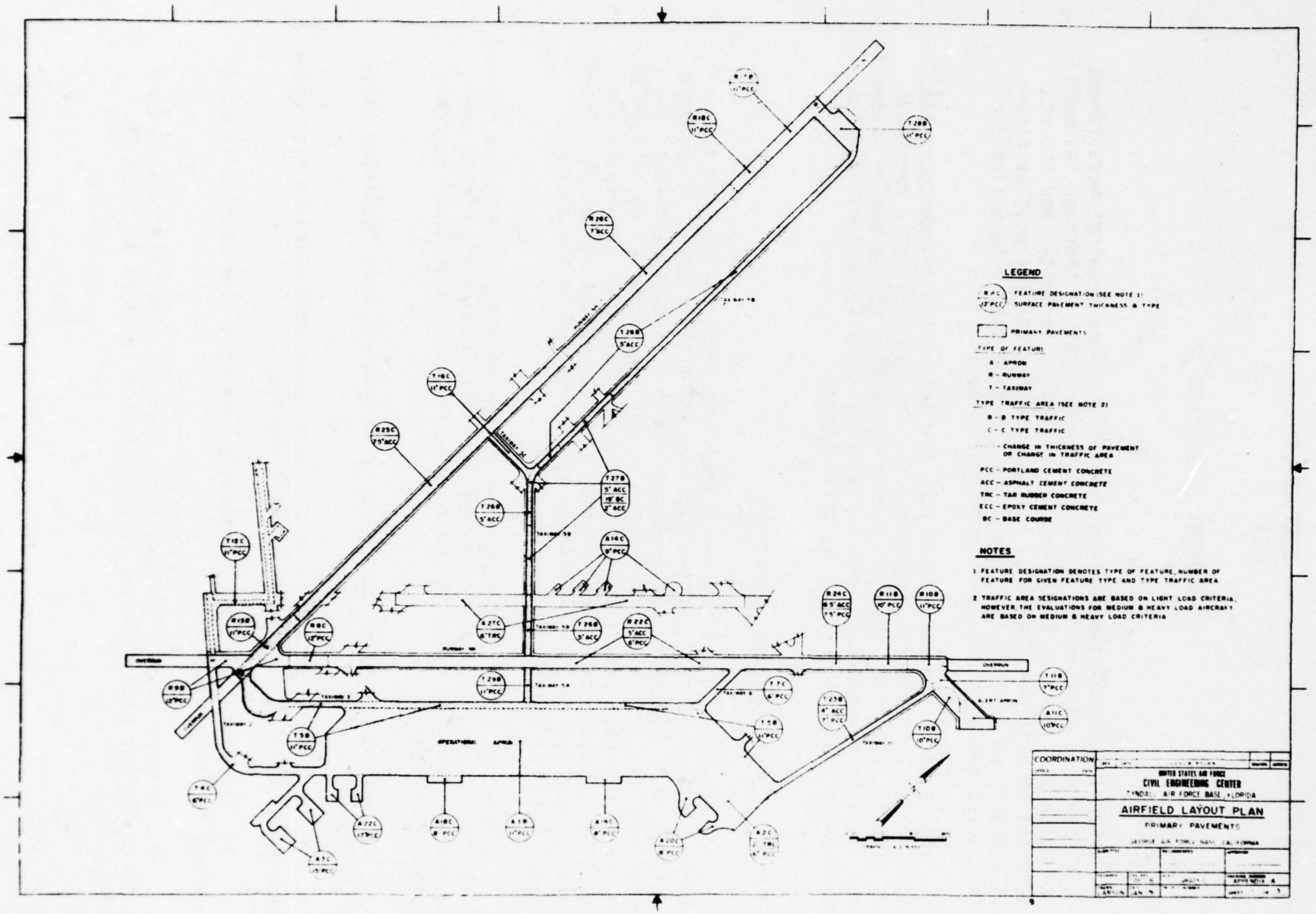


Figure 34. Identification of Features on the Airfield Layout Plan.

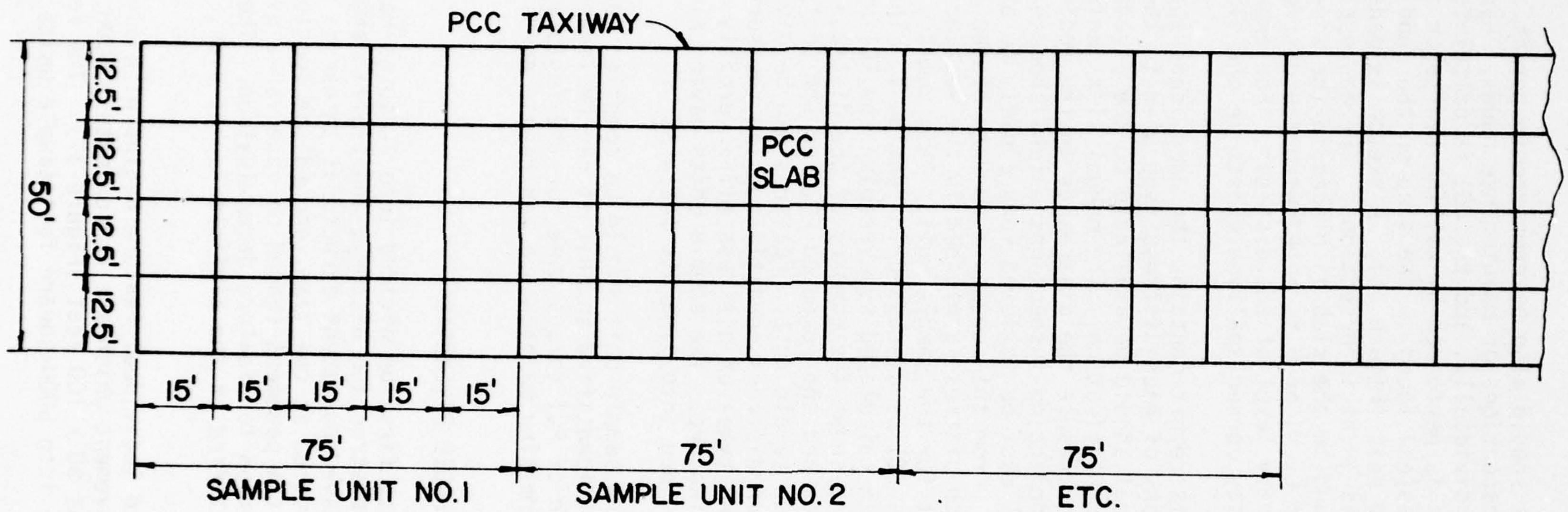


Figure 35. Illustration of Division of a Pavement Feature Into Sample Units of 20 Slabs.

Each sample unit should also be numbered to permit relocating the section for future inspections or maintenance needs. Each "sampling unit" is inspected individually, and the PCI is calculated for each. The actual inspection is performed by walking over each slab of the unit and recording distress(es) found in the slab on the condition survey data sheet for sample unit (Figure 36). A sketch is made of the sample unit using the dots as joint intersections. The appropriate number code for each distress found in the slab is placed in the square representing the slab. The letter L, M, or H is noted with the distress number code to indicate the severity level of the distress. For example, 15L indicates that low severity corner spalling exists in the slab.

Volume II of this report contains the name, description, severity levels, and photographs of each distress type used in the inspection procedure. This manual should be available to the pavement inspector to assist in distress identification. The manual also includes a detailed description of how to measure the distresses in the individual slabs. The guidelines for conducting inspections established in the distress identification manual must be followed very closely to obtain an accurate distress count. From this count, a summary of the distresses and the severities of each distress contained in the section are compiled on the survey data sheet for the sample unit. This summary is then used to compute the section's PCI as discussed in Section V. The PCI for the entire feature is then calculated by averaging the PCI of the sample units. Figure 36 also shows the summary of the distress densities located in the section and the computed PCI for the section. One data sheet is used for each sample unit. Features can be divided into two or more features based on distress condition during the survey if the density, severity, and types of distress differ greatly for different sample units in the feature. The sample units having similar distress conditions can be divided into separate features.

The PCIs for each sample unit should be compiled into a summary, with each sample unit identified so that it can be located for future inspections. A graph of PCI versus time for the features can be developed to assist in determining maintenance and repair needs.

ASPHALT- AND TAR-SURFACED PAVEMENTS

The pavement must first be divided into features based on the pavement's design, construction history, and traffic area. A pavement feature should (1) have consistent structural thickness and materials, (2) have been constructed at one time, and (3) be located in one traffic area. Condition of the pavement (based on observable distress) is an additional consideration for feature determination. The feature should be outlined and identified on the airfield layout plan, as illustrated in Figure 34.

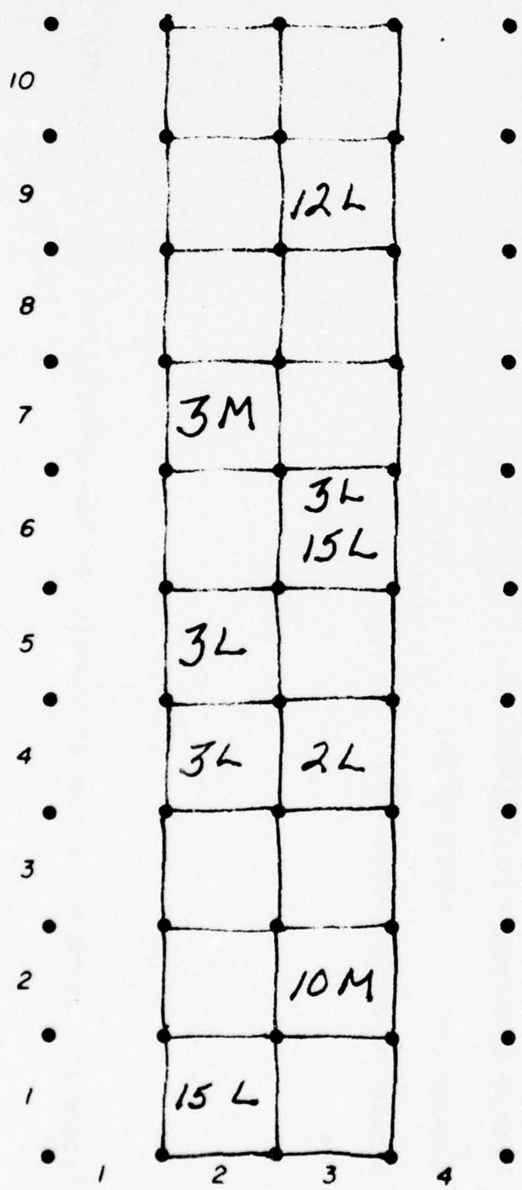
Inspection of an individual feature begins with dividing it into "sample units" of pavement which are approximately 5000 square feet in surface area (such as 50 x 100 feet (Figure 37). The reasons for dividing the feature into 5000-square feet sample units are:

JOINTED CONCRETE PAVEMENT
CONDITION SURVEY DATA SHEET FOR SAMPLE UNIT

AIRFIELD A FEATURE T6

DATE 7/6/76 SAMPLE UNIT 12

SURVEYED BY MS/MD SLAB SIZE 20 x 25 ft
20 slabs



Distress Types

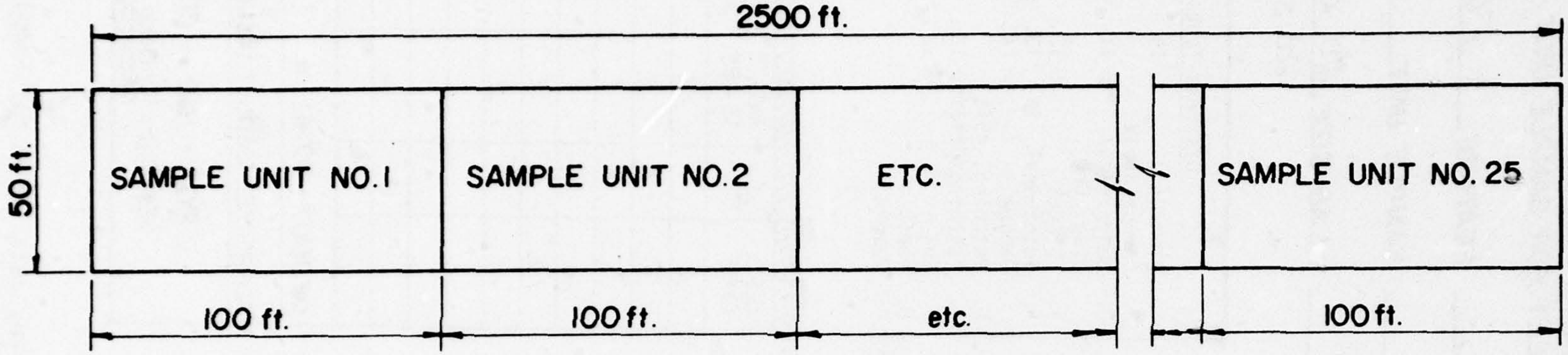
1. Blow-Up
2. Corner Break
3. Long/Trans/ Diag. Crk
4. "D" Crk
5. Joint Seal Damage
6. Patching, <5ft²
7. Patching/Utility Cut
8. Popouts
9. Pumping
10. Scaling/Map Crk/Crazing
11. Settlement/ Fault
12. Shattered Slab
13. Shrinkage Crk
14. Spalling, Joints
15. Spalling, Corner

DIST. TYPE	SEV.	NO. SLABS	% SLABS	DEDUCT VALUE
2	L	1	5	4
3	L	3	15	11
3	M	1	5	11
10	M	1	5	7
12	L	1	5	10
15	L	2	10	3
DEDUCT TOTAL				46
CORRECTED DEDUCT VALUE (CDV) q = 4				32

PCI = 100 − CDV = 68

RATING = GOOD

Figure 36. Condition Survey Data Sheet for Sample Unit Jointed Concrete.



Feature Dimension = 50 x 2500 ft.

Sample Unit = 50 x 100 ft.

Number of Sample Units = 25

Figure 37. Example Division of Asphalt- or Tar-Surfaced Pavement Feature Into Sample Units.

1. The field validation indicated this size section is very convenient to inspect and rate.

2. The deduct-density curves for each individual distress were developed based on a 5000-square foot area.

3. The corrected deduct value curves used with multiple distresses were also based on a 5000-square foot area.

This division established a convenient grid system for reference when inspecting the feature. The sample units should be numbered in a convenient manner to provide easy location for present and future inspections.

Each sample unit is inspected individually, and the PCI is calculated for each. The distress inspection is conducted by walking over the unit, measuring each distress type and severity, and recording the data on the condition survey data sheet for sample unit (Figure 38). A hand odometer is helpful in measuring the distresses, and a 10-foot straightedge and 12-inch scale should also be available. Figure 38 shows an example of a completed form. All information on the top of the data sheet could be completed; the number of the unit being inspected should be entered on the line labeled sample number. Each column on the form is used to represent a distress type, and the amount and severity of each distress located is listed in the column. Space is provided at the end of each column to sum the total distresses existing in the section.

Distress is recorded differently than for jointed concrete pavements. For example, in Figure 38 for distress No. 8 (longitudinal and transverse cracking), six different cracks were recorded on the inspection sheet as 10L, 5L, 15L, 5M, 10L, and 5M. The 10L indicates 10 feet of light severity cracking, 5M indicates 5 feet of medium severity, etc. The total amount of longitudinal and transverse cracking in this sample unit is 40 feet of light severity and 10 feet of medium. Other distress types such as No. 1 (alligator cracking) are measured in areas. Two areas of alligator cracking were recorded: a 4 x 4 foot section of medium severity, and a 2 x 3 foot section of light severity. This data sheet was found to be very convenient for recording in the field.

Volume II of this report contains type, description, severity levels, photographs, and measurement criteria for each distress type used in the survey of asphalt- and tar-surfaced pavements. This manual should be available to the pavement inspector to assist in distress identification. These guidelines must be followed closely in order to obtain an accurate distress measurement and PCI.

If the feature contains a significant portion of pavement that has a much different amount of distress than the rest of the feature, this area can be separated into another feature.

The total distress data are used to calculate the PCI of the section, as explained in Section VI. The PCIs for each sample unit should be compiled into a summary. It is important that each sample unit be

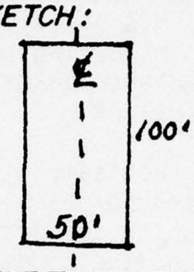
ASPHALT OR TAR SURFACED PAVEMENT
CONDITION SURVEY DATA SHEET FOR SAMPLE UNIT

AIRFIELD A FEATURE T5
DATE 6/8/76 SAMPLE UNIT 1
SURVEYED BY MD/MS/SK AREA OF SAMPLE 5000 sq ft

Distress Types

1. Alligator Cracking
2. Bleeding
3. Block Cracking
4. Corrugation
5. Depression
6. Jet Blast
7. Jt. Reflection (PCC)
8. Long. & Trans. Cracking
9. Oil Spillage
10. Patching
11. Polished Aggregate
12. Raveling/Weathering
13. Rutting
14. Shoving from PCC
15. Slippage Cracking
16. Swell

SKETCH:



EXISTING DISTRESS TYPES

	1	5	8	12		
	4x4 M	6x4 L	10L	3x10M		
	2x3 L		5L			
			15L			
			5M			
			10L			
			5M			
TOTAL SEVERITY L	6 sq ft	24 sq ft	40 ft			
TOTAL SEVERITY M	16 sq ft		10 ft	30 sq ft		
TOTAL SEVERITY H						

PCI CALCULATION

DISTRESS TYPE	DENSITY	SEVERITY	DEDUCT VALUE
1	0.12	L	7
1	0.32	M	19
5	0.48	L	2
8	0.80	L	5
8	0.20	M	5
12	0.60	M	7
DEDUCT TOTAL			45
CORRECTED DEDUCT VALUE (CDV)			25

PCI = 100 - CDV = 75

RATING = Very Good

Figure 38. Condition Survey Data Sheet for Asphalt- or Tar-Surfaced Pavements.

identified adequately so that it can be located for future surveys. A graph of PCI versus time for the features can be developed to assist in determining maintenance and repair needs.

SAMPLING PLAN

A condition survey inspection of an entire feature may require considerable effort, especially if the feature is very large. This is particularly true for asphalt- or tar-surfaced pavements containing much distress. Because of the time and effort involved, frequent surveys of an entire feature such as a heavily used runway may be beyond available manpower, funds, and time. Therefore, a sampling plan was developed to allow adequate estimation of the PCI by inspecting only a portion of the sample units in a feature. Use of the statistical sampling plan described in this section will reduce inspection time considerably without significant loss of accuracy. Use of the sampling plan presented is entirely optional. In fact, inspection of the entire feature may be necessary if exact quantities of distress must be known for contractual maintenance work.

A feature is subdivided into several sample units of approximately 20 slabs (for jointed concrete) or 5000 square feet (for asphalt- or tar-surfaced pavements). The number of sample units may range from one to over 100. How many sample units must be surveyed to obtain an adequate estimate of the feature's PCI depends on:

1. How large an error can be tolerated in the estimate of the mean feature PCI (let this error be denoted by e).

2. The desired probability that the PCI estimate will be within this limit of error (usually set fairly high, such as 95 percent).

3. An estimate of the variation of the PCI from one sample unit to another within the feature (denoted by σ).

4. The total number of sample units in the feature (denoted by N).

The allowable error e must first be expressed in terms of confidence limits. If e is the allowable error in estimating the mean PCI of the feature, and the desired probability that error will not exceed e is 95 percent,[19] the 95 percent confidence limits computed from a sample mean, assumed approximately normally distributed, are

$$\overline{X} \pm \frac{2\sigma}{\sqrt{n}} \qquad \text{[Equation 3]}$$

[19] The probability is set high so that it is reasonably certain that the error will not exceed e.

where n = number of surveyed sample units

$\overline{X}$ = the average PCI computed from sample units

σ = standard deviation of PCI.

Therefore:

$$e = \frac{2\sigma}{\sqrt{n}} \qquad \text{[Equation 4]}$$

Solving for the required sample size n gives

$$n = \frac{4\sigma^2}{e^2} \qquad \text{[Equation 5]}$$

This expression can be used if the total number of sample units in the feature is very large. However, if the computed value of n is greater than 10 percent of the total number of sample units in the feature, a revised value n´ should be used; the modified equation[20] is:

$$n' = \frac{N\sigma^2}{\left(\frac{e^2}{4}\right)(N-1) + \sigma^2} \qquad \text{[Equation 6]}$$

where n' = number of sample units required from feature

N = total number of sample units available in feature

σ = standard deviation of PCI between sample units within the feature

e = allowable error in determining the true PCI of the entire feature.

Before Equation 6 can be used to compute the required number of sample units to be inspected for a pavement feature, the N, σ, and e must be determined.

The PCIs of the individual sampling units within a given feature vary due to the heterogeneous nature of pavements and subgrade soils. Varying traffic loadings also cause differences in distress occurrence. Data were collected from several features, and the standard deviation of PCI within a feature was computed for jointed concrete pavement and for asphalt-surfaced pavements (Table 24). These standard deviations provide an estimate of the variability that exists in pavement features. These data indicate that considerable variation in pavement condition can exist in a given pavement feature.

An example will illustrate use of Equation 6 to compute the number of sample units required for inspection. Assume that a taxiway feature

[20] G. W. Snedecor and W. G. Cochran, *Statistical Methods*, 6th Ed. (Iowa State Press, 1967).

TABLE 24. SUMMARY OF DATA SHOWING THE VARIATION OF PCI BETWEEN SAMPLE UNITS WITHIN A FEATURE

Feature-Airfield	No. of Sample Units	Mean PCI	Range of PCI	PCI Standard Deviation
Asphalt-Surfaced Pavements				
Taxiway - Scott	22	88	68 - 96	9
Taxiway - Homestead	5	52	42 - 73	13
Taxiway - George	11	35	25 - 53	10
Runway - Elmendorf	7	77	71 - 82	4
Runway - Eielson	9	63	48 - 71	7
Jointed Concrete Pavements				
Apron - Scott	3	56	35 - 72	19
Taxiway - Homestead	5	60	28 - 74	19
Runway - Homestead	6	83	51 - 98	20
Runway - Wainright	3	36	23 - 57	19

of the size indicated in Figure 37 must be inspected and the mean PCI determined. Convenient sample units of 50 x 100 feet are selected; 25 units result. Determining the true PCI of the feature within $\pm$ 5 points with a confidence level of 95 percent is desired. A standard deviation of 10 points is selected based on data in Table 24. The parameters are therefore:

$$N = 25$$

$$e = 5 \text{ points}$$

$$\sigma = 10 \text{ points}$$

$$n' = \frac{25\ (10)^2}{(\frac{5^2}{4})(25 - 1) + (10)^2} = 10$$

Therefore, 10 sample units must be selected at random and be inspected the PCI of each sample unit and the mean PCI of the feature must be computed.

Figures 39 and 40 show plots developed using Equation 6 to permit ready determination of the number of required samples. The following parameters were used in developing the graphs:

For jointed concrete: σ = 15 points, e = 5 points, Confidence Level = 95 percent.

For asphalt or tar surface: σ = 10 points, e = 5 points, Confidence Level = 95 percent.

The standard deviations of 15 for jointed concrete and 10 for asphalt have been tentatively selected to represent average field conditions. The actual standard deviation for each pavement feature can be determined after the inspection has been performed using the following equation:

$$\sigma = \sqrt{\frac{\sum_{i=1}^{n} (PCI_i - \overline{PCI})^2}{n - 1}}$$

where PCI_i = pavement condition index of surveyed sample units

n = numbered of surveyed random sample units

$\overline{PCI}$ = $\Sigma PCI_i/n$

The minimum number of sample units can then be recalculated using Equation 6. However, the value of 4 in the equation should be replaced by the square of the t value obtained from the t-student distribution based on the number of random samples surveyed and 95 percent confidence.

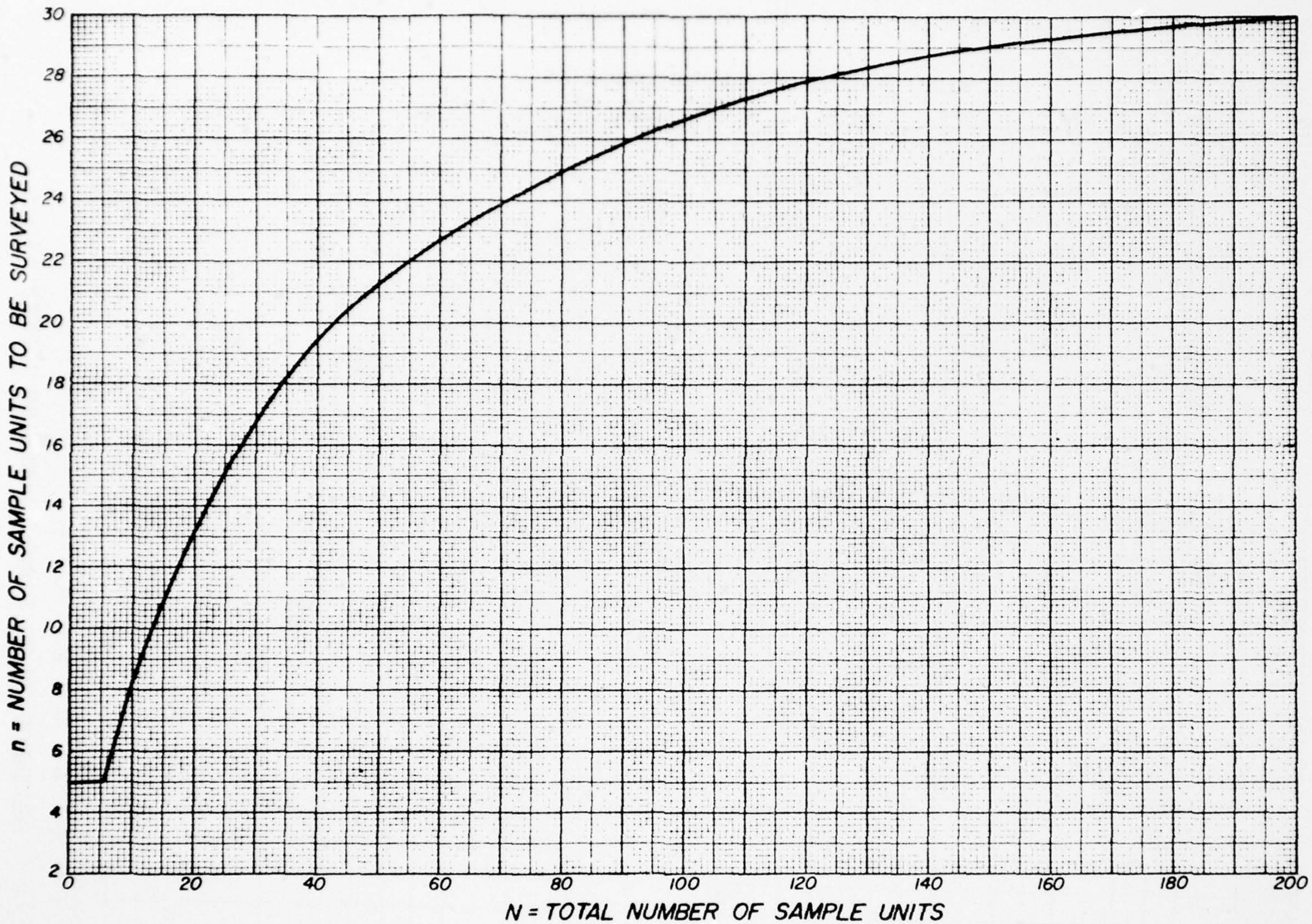


Figure 39. Plot for Determining Number of Sample Units Required for Jointed Concrete Pavement.

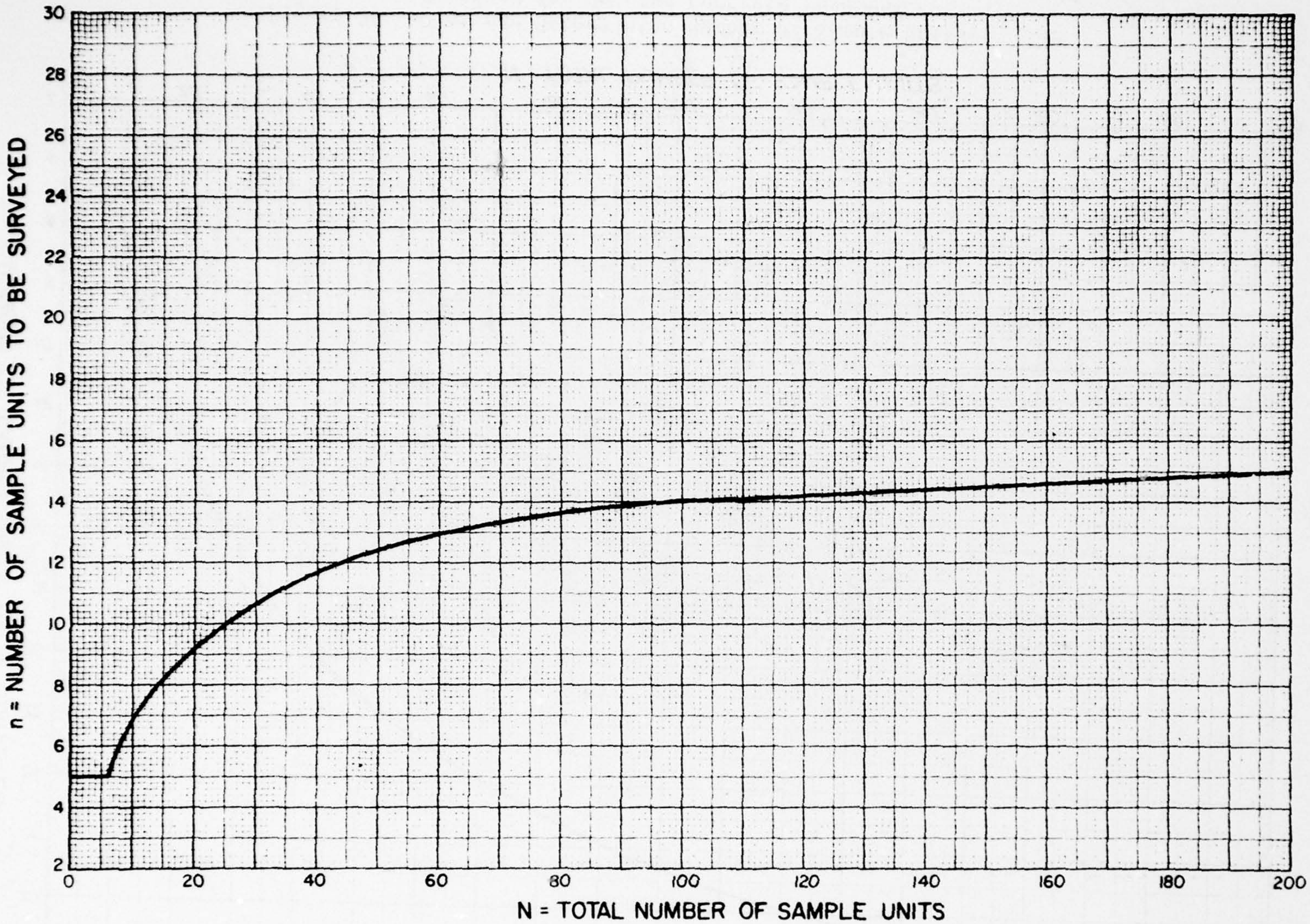


Figure 40. Plot for Determining Number of Sample Units Required for Asphalt- or Tar-Surfaced Pavements.

SELECTION OF SAMPLES

Determination of how to select the sample units is as important as determining the minimum number of samples. Samples must be selected randomly to assure an unbiased PCI. If the number of sample units in a feature exceeds 10, stratifying the feature is recommended. Stratifying the feature involves dividing it into a number of parts called strata. An equal number of sample units are randomly selected from each strata, and the sample mean is computed by averaging the PCI of all surveyed sample units, as illustrated in the following example.

Figure 37 shows the feature to be inspected; it contains a total of 25 sample units numbered from 1 to 25. The required minimum number of sample units is determined to be 10 (from Equation 6 or Figure 39). Strata can be selected in several ways, such as dividing the feature into five strata:

Strata 1	Sample units 1 through 5
Strata 2	Sample units 6 through 10
Strata 3	Sample units 11 through 15
Strata 4	Sample units 16 through 20
Strata 5	Sample units 21 through 25

Two sample units are selected at random from each strata using a random number table, such as Table 25. For example, units can be selected for this example by starting at columns 05 and 06 and row 10 and proceeding down the page selecting the first two numbers between 01 and 05, which are 03 (row 16) and 01 (row 25). The process would then be repeated for the other four strata. If the required units have not been obtained when the bottom of the column is reached, they can be obtained by proceeding up from row 49 in columns 20 and 21. The numbers selected using this procedure are circled in Table 25.

Strata	Sample Units
Strata 1 (1 - 5)	03, 01
Strata 2 (6 - 10)	09, 10
Strata 3 (11 - 15)	12, 13
Strata 4 (16 - 20)	16, 17
Strata 5 (21 - 25)	21, 23

Therefore, sample units numbered 01, 03, 09, 10, 12, 13, 16, 17, 21, and 23 must be inspected and the PCI determined for each. The mean PCI of the taxiway feature is then estimated as the mean of all 10 sample units. To illustrate how the results of this sampling compare to

TABLE 25. TYPICAL RANDOM NUMBER TABLE

	00-04	05-09	10-14	15-19	20-24	25-29	30-34	35-39	40-44	45-49
00	54463	22662	65905	70639	79365	67382	29085	69831	47058	08186
01	15389	85205	18850	39226	42249	90669	96325	23248	60933	26927
02	85941	40756	82414	02015	13858	78030	16269	65978	01385	15345
03	61149	69440	11286	88218	58925	03638	52862	62733	33451	77455
04	05219	81619	10651	67079	92511	59888	84502	72095	83463	75577
05	41417	98326	87719	92294	46614	50948	64886	20002	97365	30976
06	28357	94070	20652	35774	16[illegible]49	75019	21145	05217	47286	76305
07	17783	00015	10806	83091	91530	36466	39981	62481	49177	75779
08	40950	84820	29881	85966	62800	70326	84740	62660	77379	90279
09	82995	64157	66164	41180	10089	41757	78258	96488	88629	37231
→ 10	96754	17[illegible]76	55659	44105	47361	34833	86679	23930	53249	27083
11	34357	88040	53364	71726	45690	66334	60332	22554	90600	71113
12	06318	37403	49927	57715	50423	67372	63116	48888	21505	80182
13	62111	52820	07243	79931	89292	84767	85693	73947	22278	11551
14	47534	09243	67879	00544	23410	12740	02540	54440	32949	13491
15	98614	75993	84460	62846	59844	14922	48730	73443	48167	34770
16	24867	03[illegible]48	44898	09351	98795	18644	39765	71058	90368	44104
17	96887	12[illegible]79	80621	66223	66085	78285	02432	53342	42846	94771
18	90801	21472	42815	77408	37390	76766	52615	32141	30268	18106
19	55165	77312	83666	36028	28420	70219	81369	41943	47366	41067
20	75884	12952	84318	95108	72305	64620	91381	89872	45375	85436
21	16777	37116	58550	42958	21460	43910	01175	87894	81378	10620
22	46230	43877	80207	88877	89380	32992	91380	03164	98656	59337
23	42902	66892	46134	01432	94710	23474	20423	60137	60609	13119
24	81007	00333	39693	28039	10[illegible]54	95425	39220	19774	31782	49037
25	68089	01[illegible]22	51111	72373	06902	74373	96199	97017	41273	21546
26	20411	67081	89950	16944	93054	87687	96693	87236	77054	33848
27	58212	13[illegible]60	06468	15718	82627	76999	05999	58680	96739	63700
28	70577	42866	24969	61210	76046	67699	42054	12696	93758	03283
29	94522	74358	71659	62038	79643	79169	44741	05437	39038	13163
30	42626	86819	85651	88678	17401	03252	99547	32404	17918	62880
31	16051	33763	57194	16752	54450	19031	58580	47629	54132	60631
32	08244	27647	33851	44705	94211	46716	11738	55784	95374	72655
33	59497	04392	09419	89964	51211	04894	72882	17805	21896	83864
34	97155	13428	40293	09985	58434	01412	69124	82171	59058	82859
35	98409	66162	95763	47420	20792	61527	20441	39435	11859	41567
36	45476	84882	65109	96597	25930	66790	65706	61203	53634	22557
37	89300	69700	50741	30329	11658	23166	05400	66669	48708	03887
38	50051	95137	91631	66315	91428	12275	24816	68091	71710	33258
39	31753	85178	31310	89642	98364	02306	24617	09609	83942	23716
40	79152	53829	77250	20190	56535	18760	69942	77448	33278	48805
41	44560	38750	83635	56540	64900	42912	13953	79149	18710	68618
42	68328	83378	63369	71381	39564	05615	42451	64559	97501	65747
43	46939	38689	58625	08342	30459	85863	20781	09284	26333	91777
44	83544	86141	15707	96256	23[illegible]68	13782	08467	89469	93842	55349
45	91621	00881	04900	54224	46177	55309	17852	27491	89415	23466
46	91896	67126	04151	03795	59077	11848	12630	98375	52068	60142
47	55751	62515	21108	80830	02263	29303	37204	96926	30506	09808
48	85156	87689	95493	88842	00664	55017	55539	17771	69448	87530
49	07521	56898	12236	60277	39102	62315	12239	07105	11844	01117

the true PCI of the feature, consider the results shown in Figure 41, which shows the PCI measurements for each of the 25 sections. The true overall mean is 36. The mean PCIs of the 10 randomly selected sections is 38, which is within $\pm$ 5 points of the true mean of 36.

One of the major objections to "random sampling" some engineers express is the problem of not including a very "poor" or "excellent" sample unit which may exist in the feature. However, one or more additional samples selected by the engineer can be inspected if desired; the following equation must then be used to compute the mean PCI:

$$PCI_f = \frac{(N - C)}{N} \overline{PCI_1} + \frac{C}{N} \overline{PCI_2} \qquad \text{[Equation 7]}$$

where: PCI_f = overall PCI of feature

N = total number of sample units in the feature or subfeature

C = number of additional sample units

$\overline{PCI_1}$ = arithmetic mean of PCI for random units

$\overline{PCI_2}$ = arithmetic mean of PCI for the additional sample units.

For example, if the mean PCI of the 10 sample units previously discussed was 38, and one additional section inspected because it had serious distress had a PCI of 10, the final PCI_f of the feature would be computed as:

$$PCI_f = \frac{(25 - 1)}{25} (38) + \frac{1}{25} (10) = 37$$

Pavement Feature: Taxiway 5
Total No. of Units: 25
Date of Survey: 7/13/1976

Unit No.	Unit Area Sq Ft	PCI	Unit No.	Unit Area Sq Ft	PCI
1	5000	42	16	5000	35
2	5000	33	17	5000	22
3	5000	53	18	5000	30
4	5000	39	19	5000	39
5	5000	23	20	5000	35
6	5000	25	21	5000	32
7	5000	36	22	5000	41
8	5000	38	23	5000	49
9	5000	35	24	5000	30
10	5000	25	25	5000	22
11	5000	32			
12	5000	45			
13	5000	40			
14	5000	55			
15	5000	46			

Average PCI for Feature: 36
Pavement Rating: Poor

Figure 41. Feature Summary--Asphalt- or Tar-Surfaced Pavement.

SECTION VIII

TENTATIVE GUIDELINES FOR DETERMINING MAINTENANCE AND REPAIR REQUIREMENTS

INTRODUCTION

There are several maintenance and repair (M&R) alternatives that can be used to restore the structural integrity and/or operational condition of a pavement feature. However, there are no guidelines or rational methods for determining the most economical alternative and priority of repair based on the existing pavement feature condition. Such procedures are needed to provide efficient planning and use of available maintenance funds. A major reason for the lack of such procedures has been the lack of a comprehensive pavement condition indicator that relates to maintenance requirements. Development of the PCI presented in this report, however, has eliminated this deterrent.

This section provides tentative guidelines for determining maintenance and repair needs and priorities based on the PCI. The following subsections define M&R categories and describe tentative guidelines relating the PCI to M&R requirements.

PAVEMENT MAINTENANCE AND REPAIR CATEGORIES

M&R can be classified into four main categories:

1. Preventive--Maintenance activities that preserve pavement condition and retard its deterioration. Preventive maintenance may or may not increase the PCI; it does not increase the pavement's structural capacity. Preventive maintenance includes joint seal, crack filling of light severity cracks (nonspalled), fog seal, and application of rejuvenators.

2. Localized--Maintenance activities that restore the pavement's operational condition. Localized maintenance usually increases the PCI but does not increase the pavement structural capacity. It includes deep patching, crack filling of medium or high severity cracks, removal of bumps or shoving with a heater-planer, grinding, and slab-jacking.

3. Major--Maintenance activities that restore pavement condition; an extensive form of localized maintenance. Major maintenance increases the PCI considerably but does not increase the pavement's structural capacity. Major repair includes deep patching over 3 percent of the pavement area for asphalt- or tar-surfaced pavements, and slab replacement over 3 percent of the slabs in a jointed concrete pavement.

4. Overall--Maintenance and repair activities that cover the entire pavement feature. Overall maintenance usually increases the PCI to an excellent rating and may increase the pavement structural capacity. Overall M&R includes overlay, surface treatment, and reprocessing.

DETERMINATION OF M&R REQUIREMENTS BASED ON PAVEMENT CONDITION

Choice of any of the above M&R categories is a function of the existing pavement condition, economic considerations, and the mission of the pavement feature. To relate the PCI to M&R needs, the pavement condition rating scale (0 to 100) has been divided into three zones (Table 26). The general categories of needed M&R are determined from this table based on the zone in which the PCI is located. The A and B values that identify the zones are functions of pavement feature mission as defined at the bottom of the table for runways, taxiways, and aprons. These values were tentatively selected based on pavement condition rating results of numerous pavement features at nine airfields.

As previously stated, the PCI measures the pavement structural integrity and surface operational condition based on measured distress types, severity, and density. The PCI, however, does not directly measure the pavement structural capacity (for change in traffic mission), skid resistance, or long-wave roughness. The direct measurement of each of these items requires special equipment and personnel.

Every Air Force base receives periodic (approximately once every 5 years) skid resistance testing by a specialty team from AFCEC; this is generally sufficient. In-depth evaluation of the pavement structural capacity is also provided by HQUSAF on request from the base civil engineer through the major command. This evaluation of structural capacity is usually requested when the traffic mission changes or the pavement condition warrants overall repair or reconstruction. The latter can be justified by the value of the PCI. Although the PCI provides an adequate measurement of localized roughness, it cannot detect long-wave roughness. However, serious long-wave roughness will prompt pilot complaints, which should justify special roughness measurement by AFCEC.

A rational procedure for determining maintenance and repair requirements for a pavement feature is shown in Figure 42 and described briefly below.

1. The base civil engineer performs the pavement condition survey and calculates the PCI as outlined in this report. Before M&R requirements are determined based on the PCI, it should be ascertained whether a change in traffic mission, pilot complaints from long-wave roughness (localized roughness is adequately considered in the PCI), or a skid hazard exist. If any of these situations exist, the base civil engineer may request that the AFCEC conduct a pavement evaluation to evaluate these problem areas.

2. If none of the above items exist, preventive and localized or major and overall repair can be selected based on the value of the PCI as follows:

a. If the PCI is greater than or equal to A, only preventive and localized maintenance are performed when needed.

b. If the PCI is between A and B (i.e., warning zone), the PCI should be recalculated assuming all needed preventive and localized

TABLE 26. RELATIONSHIP BETWEEN PCI AND M&R CATEGORIES

		M&R Category	
PCI	Zone	Preventive and Localized M&R	Major and Overall M&R
PCI $\geq$ A	Zone I	May be needed	Not needed within next 2 years
B $\leq$ PCI < A	II	May be needed	Possibly needed within next 2 years
PCI < B	Zone III	May be needed	Definitely needed within next 2 years

A and B Values

Mission	A	B
Runway	65	50
Taxiway	60	40
Apron	60	40

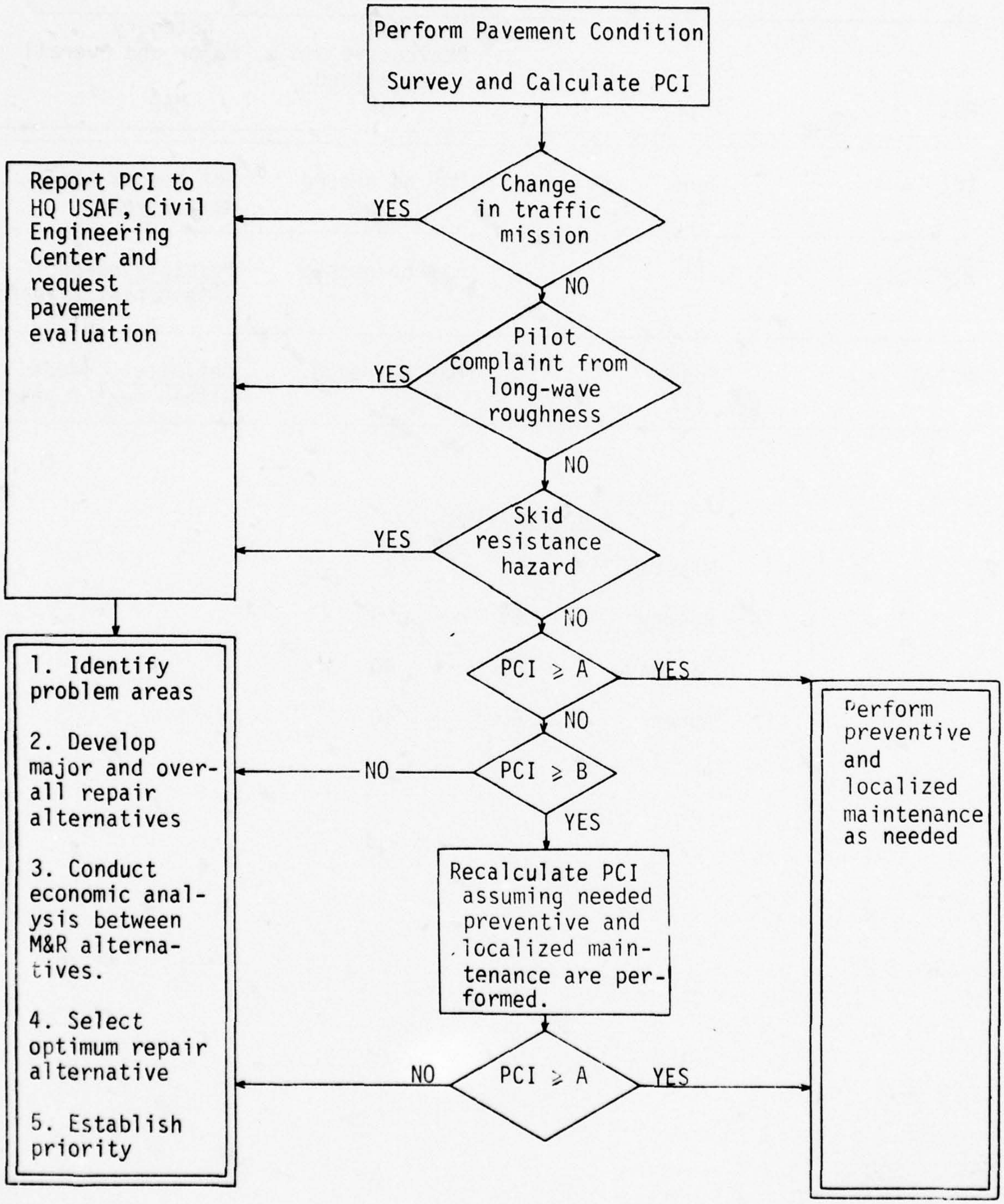


Figure 42. Procedure for Determining M&R Requirements for a Pavement Feature Based on the PCI Value.

maintenance is performed. If the recalculated value of the PCI is greater than or equal to A, only preventive and localized maintenance is applied. If the recalculated PCI is less than A, economic analysis is conducted to select the optimum repair alternative.

c. If the PCI is below B, major and overall repair alternatives should be developed and economic analysis should be conducted to select the optimum alternative.

3. After repair requirements are identified, priorities should be established based on the value of the PCI and utilization of the pavement feature (i.e., runway, taxiway, or apron). Timing of maintenance and repair application is also important when establishing priorities and should be considered when conducting economic analysis of repair alternatives. This point can be illustrated by considering the PCI for a pavement feature over several years (Figure 43). At time T_1 the cost necessary to restore a pavement to its original operational condition is undoubtedly much less than the cost necessary at time T_2.

SUMMARY OF M&R METHODS CURRENTLY USED FOR REPAIRING DIFFERENT DISTRESS TYPES

Tables 27 and 28 give brief summaries of the common methods of maintenance and repair used for different distress types on asphalt- or tar-surfaced and jointed concrete pavements. Although these repair methods are already familiar to base civil engineers, the tables will be helpful in developing maintenance and repair alternatives for a pavement feature. Although several methods of M&R can be used for a specific distress, the appropriate alternatives are functions of the distress density, other distress types in the pavement feature, and interruption of traffic operations.

FIELD CASE STUDIES

Four field case studies of different Air Force bases illustrate use of the guidelines for determining M&R requirements for pavement features.

Field Case Study No. 1

1. Pavement Feature Identification: Primary taxiway 5B, feature No. T26B, George AFB, CA. The feature is 75 feet wide and 5760 feet long.

2. Pavement Structure:

Surface:	5 inch, asphalt concrete
Base:	6 inch, sandy gravel, California Bearing Ratio (CBR) = 40
Subbase:	4 inch, gravelly sand, CBR = 20
Subgrade:	clayey silty sand, CBR = 5

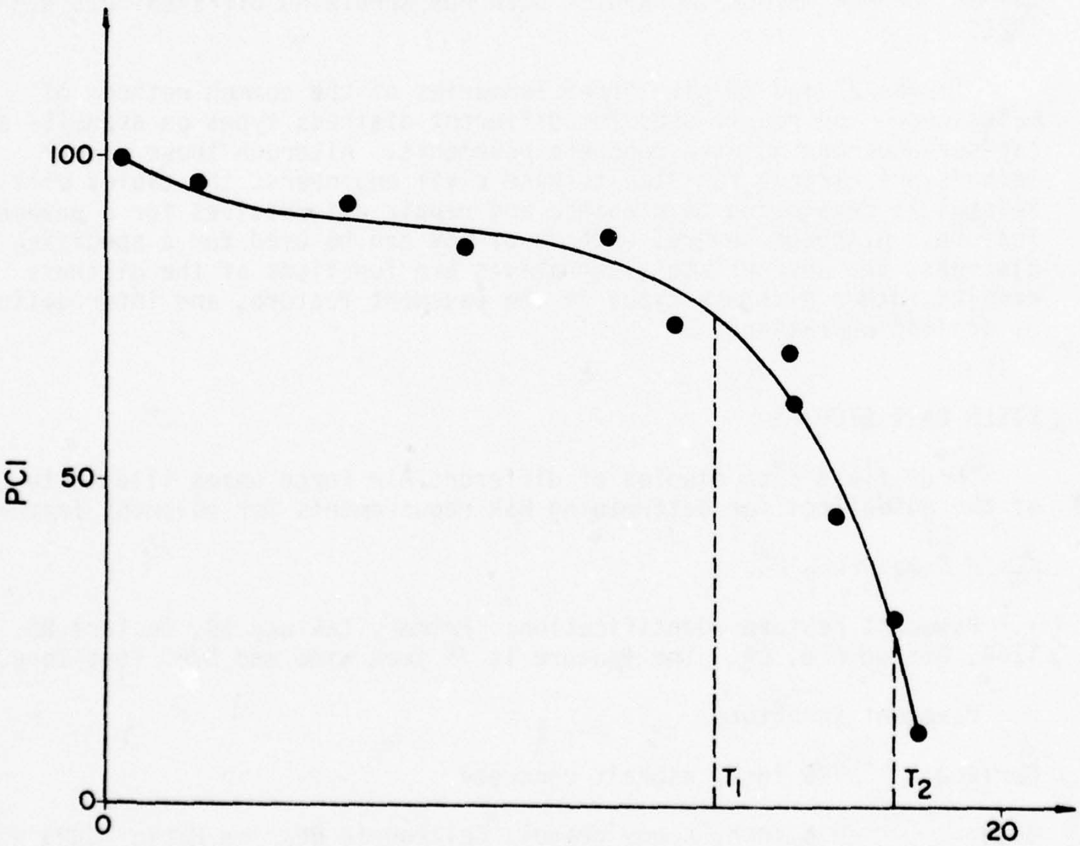


Figure 43. PCI Time-History Curve for a Pavement Feature.

TABLE 27. M&R METHODS FOR DISTRESS TYPES ON ASPHALT- OR TAR-SURFACED PAVEMENTS

Distress Type	Severity Level	Maintenance and Repair
1. Alligator Crack	L	Do nothing, deep patch, or consider overlay if there is a large amount.
	M	Do nothing, deep patch, overlay, or reconstruction.
	H	Deep patch, overlay, or reconstruction.
2. Bleeding		Remove with blade or heater-planer, apply and roll sand coat, or overlay.
3. Block Cracking	L	Do nothing, or crack filling, slurry seal, fog seal, or rejuvenator.
	M	Crack filling or slurry seal, fog seal, or rejuvenator.
	H	Reprocessing or crack filling that may be followed by slurry seal, fog seal, rejuvenator, or overlay.
4. Corrugation	L	Do nothing or remove with blade or heater-planer.
	M	Remove with blade or heater-planer, reprocessing, or surface leveling and overlay.
	H	Reprocessing, reconstruction, or surface leveling and overlay.
5. Depression	L	Do nothing or shallow patch.
	M	Do nothing, shallow patch, deep patch, or surface level and overlay.
	H	Shallow patch, deep patch, or surface level and overlay.
6. Jet Blast Erosion		Do nothing, tar seal, deep patch, or apply a rejuvenator.

TABLE 27. M&R METHODS FOR DISTRESS TYPES ON ASPHALT- OR TAR-SURFACED PAVEMENTS (CONTINUED)

Distress Type	Severity Level	Maintenance and Repair
7. Joint Reflection Crack	L	Do nothing or crack filling.
	M	Sealing, or crack filling, or shallow patch.
	H	Crack filling, shallow patch, or surface seal.
8. Longitudinal and Transverse Crack	L	Do nothing or crack filling.
	M	Sealing, replace sealant, crack filling, or shallow patch.
	H	Crack filling, shallow patch, or surface seal.
9. Oil Spillage		Do nothing, shallow patch, tar-rubber overlay when economically advisable, or tar-emulsion seal coat.
10. Patching and Utility Cut Patch	L	Do nothing.
	M	Do nothing, surface leveling, or replace patch.
	H	Replace patch.
11. Polished Aggregate		Do nothing, grooving, or thin overlay.
12. Raveling and Weathering	L	Do nothing or fog seal.
	M	Surface seal (surface treatment slurry seal, sand seal, etc.).
	H	Surface seal or thin overlay.
13. Rutting	L	Do nothing or shallow patch.
	M	Shallow patch, deep patch, surface leveling and overlay, reprocessing, or reconstruction.
	H	Shallow patch, deep patch, reconstruction, or overlay.

TABLE 27. M&R METHODS FOR DISTRESS TYPES ON ASPHALT- OR TAR-SURFACED PAVEMENTS (CONCLUDED)

Distress Type	Severity Level	Maintenance and Repair
14. Shoving	L	Do nothing or clean and seal concrete joint if possible.
	M	Do nothing or remove with blade or heater-planer.
	H	Remove with blade or heater-planer.
15. Slippage Crack		Do nothing or deep patch.
16. Swell	L	Do nothing.
	M	Heater-planer, surface leveling, reprocessing, or reconstruction.
	H	Heater-planer, surface leveling, reprocessing, or reconstruction.

TABLE 28. M&R METHODS FOR DISTRESS TYPES ON JOINTED CONCRETE PAVEMENTS

Distress Type	Severity Level	Maintenance and Repair
1. Blow-Up	L	Deep patch, slab grinding and resealing joint.
	M	Deep patch or slab replacement.
	H	Deep patch or slab replacement.
2. Corner Break	L	Do nothing or crack filling.
	M	Do nothing or crack filling.
	H	Crack filling or deep patch.
3. Longitudinal, Transverse, and Diagonal Crack	L	Do nothing or crack filling.
	M	Crack filling.
	H	Crack filling or deep patch.
4. "D" Cracking	L	Do nothing, shallow patch, or deep patch.
	M	Shallow patch or deep patch.
	H	Shallow patch, deep patch, or slab replacement.
5. Joint Seal Damage	L	Do nothing.
	M	Do nothing or replace sealant.
	H	Replace sealant.
6. Small Patching	L	Do nothing.
	M	Do nothing or replace patch.
	H	Replace patch.
7. Large Patching and Utility Cut	L	Do nothing.
	M	Do nothing, repair patch, or replace patch.
	H	Repair patch, replace patch, or slab replacement.

TABLE 28. M&R METHODS FOR DISTRESS TYPES ON JOINTED CONCRETE PAVEMENTS (CONCLUDED)

Distress Type	Severity Level	Maintenance and Repair
8. Popouts		Do nothing.
9. Pumping		Seal joints, or drainage correction and/or undersealing.
10. Scaling, Map Cracking, and Crazing	L	Do nothing.
	M	Do nothing or shallow patch.
	H	Shallow patch or slab replacement.
11. Settlement (Faulting)	L	Do nothing or grinding.
	M	Do nothing, shallow patch, grinding, or slab jacking.
	H	Grinding, slab-jacking, or shallow patch.
12. Shattered Slab	L	Do nothing or crack filling.
	M	Crack filling or slab replacement.
	H	Crack filling or slab replacement.
13. Shrinkage Cracks		Do nothing.
14. Spalling Along Joints	L	Do nothing or small patch.
	M	Do nothing, crack filling, shallow patch, or deep patch.
	H	Crack filling, shallow patch, or deep patch.
15. Corner Spall	L	Do nothing or crack filling.
	M	Do nothing, crack filling, or small patch.
	H	Small patch.

3. Background Information: A recent in-depth pavement evaluation (structural capacity) performed at George AFB by a team from AFCEC, Tyndall AFB, resulted in the following conclusion:

> "Taxiway 5B (T26B) is at or rapidly approaching a failed condition. All pavement components are beyond restoration by normal maintenance. Environmental erosion, load repetition, and a weak subgrade soil has resulted in a progressive shear failure. Reconstruction will be required in the near future. Strengthening of the base course and additional subgrade cover is required. Both objectives can probably be accomplished by recycling the existing surface and some of the base course and placing a new wearing course. An alternative is to construct a pavement on top of the existing facility. The existing pavement is not suitable for a bonded overlay placement."[21]

The CERL project staff visited George AFB to determine the Pavement Condition Index (PCI) of the taxiway feature and to conduct preliminary validation of the tentative guidelines for determining M&R needs presented in this section.

4. Pavement Condition Index: Two members of the CERL project staff and the George AFB civil engineer inspected the taxiway according to the guidelines presented in Section VII. Eleven 37-foot-wide (half the width of the feature) and 100-foot-long sample units were surveyed. The sample units were selected at random on both sides of the centerline of the taxiway. Table 29 summarizes the pavement distress and calculated PCI for each sample unit.

5. Maintenance and Repair Needs: As Table 29 shows, the average PCI for the entire feature is calculated to be 35. This value is below the "B" value for taxiways, which is 40. Table 26 and Figure 42 indicate that, based on the determined PCI value, a major and/or overall repair is definitely needed. The several possible alternatives should be analyzed, and an economic analysis should be conducted to determine the best solution. This conclusion agrees with the conclusion reached by the AFCEC based on full-scale in-depth pavement evaluation, analysis of several pavement core samples, and performance of in-situ CBR tests.

Field Case Study No. 2

1. Pavement Feature Identification: East/west runway, stations 46 + 00 to 124 + 75. Elmendorf AFB, Anchorage, AK. The feature is 200 feet wide and 7875 feet long.

2. Pavement Structure:

    a. Stations 46 + 00 to 66 + 00

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[21] *Airfield Pavement Evaluation and Condition Survey Report, George AFB, California* (AFCEC, February 1976).

TABLE 29. SUMMARY OF PAVEMENT DISTRESS, PCI, AND $\overline{PCR}$ FOR TAXIWAY 5B (FEATURE T26B), GEORGE AFB

Distress Type	Sev. Level	Distress density, in percent, for each sample unit 1	2	3	4	5	6	7	8	9	10	11
1. Alligator cracking	L	2.2	2.2	0.2	8.6	4.7	1.5	1.9	11.0	3.9	1.1	1.7
	M	1.1	3.6	1.4	2.0	24.4	20.3	7.7	1.9	2.7	5.7	1.4
	H											
2. Bleeding	L		4.3									
	M											
	H											
3. Block cracking	L	73	62	45.9	40.5	37.8	20.0	75.7	67.6	67.6	51.4	78.3
	M											
	H											
5. Depression	L		0.4									
	M											
	H											
8. Longitudinal and transverse cracking	L	0.8	0.7	3.9	3.2	2.8	0.5	3.7	1.9	4.2	2.0	
	M			0.4								
	H											
10. Patching	L						52.0					
	M											
	H											
13. Rutting	L	1.1				4.3		5.4		0.8		1.1
	M											2.2
	H										4.4	
PCI		42	33	53	39	23	25	36	38	35	25	32

Average PCI for feature = 35

Surface: 4 inch, asphalt concrete

Base: 6 inch, crushed gravel, CBR = 80

Subbase: 20 inch, gravel, 100 percent compaction
42 inch, gravel, 95 percent compaction
6 inch, old PCC slab

b. Stations 66 + 00 to 122 + 00

Surface: 4 inch, asphalt concrete

Base: 4 inch, crushed gravel, CBR = 80

Subbase: 6 inch, old PCC slab

3. Background Information: Before visiting Elmendorf AFB, the project staff at CERL was informed that the runway is scheduled for overlay in the near future. However, the reason for the overlay was not given at that time.

4. Pavement Condition Index: Seven 38-foot-wide and 100-foot-long sample units were inspected and rated by the CERL staff and the Alaska major command pavement engineer. The sample units were selected at 1000-foot intervals along the runway. Table 30 summarizes the pavement distress and calculated PCI for each sample unit.

5. Maintenance and Repair Needs: The average PCI for the feature was calculated to be 77. The feature is therefore rated as "very good" and is well above the "A" value for runways, which is 65. Therefore, only preventive and localized repair should be performed as needed.

After this determination had been made, the project staff asked the major command about the reason for the overlay. The reason was that the runway cross section was constructed parabolically, without adequate transverse slope for surface water drainage. This fact was reported by an AFCEC team which found that the runway had a very low skid number. The major command engineer, however, agreed that the runway condition is very good otherwise, and would not require repair if the cross slope was adequate. Based on the recommended procedure for determining M&R requirements (Figure 43), the project staff agrees that the need for overlay is justified based on skid resistance problems, but not on pavement distress conditions.

Field Case Study No. 3

1. Pavement Feature Identification: Taxiway #1, feature no. TIA, Homestead AFB, FL. The surveyed feature, which was constructed in 1961-1962, was 50 feet wide and 1250 feet long.

2. Pavement Structure:

Surface: 16 inch, jointed concrete pavement, 25 x 25 foot slabs.

TABLE 30. SUMMARY OF PAVEMENT DISTRESS, PCI, AND $\overline{PCR}$ FOR EAST/WEST RUNWAY AT ELMENDORF AFB

Distress Type	Severity Level	Distress Density, Percent							
		Sample Unit No.							
		1	2	3	4	5	6	7	
Alligator Cracking	L	0.94		0.13		0.33			
	M								
	H								
Longitudinal and Transverse Cracking	L	10.34	8.74	6.1	7.5	7.0	8.1	9.1	
	M			0.7	0.1	0.15	0.33	0.44	
	H								
PCI		71	78	82	77	72	80	78	Average PCI for Feature = 77

Subgrade: lime rock, k (subgrade modulus) = 500 pci.

3. Background Information: The feature was rated by the current USAF condition survey procedure as fair in December 1975. No major repair or reconstruction was scheduled at the time the CERL project staff performed the inspection.

4. Pavement Condition Index: The taxiway feature consisted of one hundred 25 x 25 foot slabs. It was divided into five sample units containing 20 slabs each; all the sample units were inspected. Table 31 shows the results of the inspection and the calculated PCI for each sample unit. The entire feature was rated by four raters (two engineers from CERL, the major command pavement engineer, and the project technical monitor from AFCEC).

5. Maintenance and Repair Needs: The average PCI for the taxiway feature is 60, which places it in zone 1 for taxiways. According to Figure 42 only preventive and localized repair should be performed as needed. However, since the PCI for the feature is near the top of the warning zone, the PCI was recalculated assuming that preventive and localized repair activities are performed (Table 32). The recalculated value for the PCI was found to be 66, which is well above the A value of 60. Therefore, it is recommended that localized maintenance be performed and that the feature be reinspected at least annually to monitor any change in the PCI.

Field Case Study No. 4

1. Pavement Feature Identification: North runway, feature #4C, Fort Wainwright, Fairbanks, AK. The feature is 150 feet wide and 5000 feet long.

2. Pavement Structure:

Surface: 6 inch, jointed concrete pavement, concrete flexural strength is 650 psi.

Base: 16 inch, sandy gravel, k = 200 pci.

Subgrade: silt, CBR = 7.

3. Background Information: The feature which was constructed during 1940 - 1941, was selected for inspection by the project staff because it is subjected to severe cold weather. The inspection team (CERL project staff and the major command pavement engineer) was accompanied by an officer from the base operation office who expressed dissatisfaction with the condition of the pavement feature and indicated that they have been trying to initiate a major repair or reconstruction project for the past 2 years.

4. Pavement Condition Index: Due to time limitations, only three sample units were surveyed. The units were randomly selected 1500 to 2000 feet apart. It must be emphasized that three sample units in a feature of that size is not enough to obtain an accurate PCI for the feature; the

TABLE 31. SUMMARY OF PAVEMENT DISTRESS, PCI, AND $\overline{PCR}$ FOR TAXIWAY #1 AT HOMESTEAD AFB

Distress Type	Sev. Level	Distress Density, Percent Slabs Sample #1	Sample #2	Sample #3	Sample #4	Sample #5
2; Corner Break	L	15.	45.	5.0	10.	25.
	M	5.			5.	
	H					
3; Long/Trans/ Diag. Crk.	L	30.		5.0		5.
	M					15.
	H					10.
6; Patching Less than 5 ft^2	L	10.			5.	
	M					
	H					
10; Scaling/Map Crk/Crazing	L	100.	100.	100.	100.	100.
	M					
	H					
12; Shattered Slab	L					10.
	M					
	H					
13; Shrinkage Crk.	L	5.				
	M					
	H					
PCI		60	64	74	74	28

Ave. PCI for feature = 60

TABLE 32. RECALCULATED PCI VALUES FOR TAXIWAY AT HOMESTEAD AFB ASSUMING PREVENTIVE AND LOCALIZED MAINTENANCE ACTIVITIES ARE PERFORMED

Sample Unit No.	PCI	Preventive and Localized Repair	Recalculated PCI
1	60	Crack filling of medium severity corner break.	62
2	64	Do nothing.	64
3	74	Do nothing.	74
4	74	Crack filling of medium corner break.	76
5	28	Crack filling of medium and high severity longitudinal/transverse/diagonal crack.	52
Ave. PCI	60		66

number of sample units for a pavement feature should be determined based on the guidelines provided in Section VII. Table 33 summarizes the pavement distresses found during the survey, and the calculated PCI. The PCI for sample unit 3 is much higher than for samples 1 and 2 because the area from which sample 3 was randomly selected recently received a major repair--several slabs were replaced and many of the other slabs were deep patched.

5. Maintenance and Repair Requirement: The average PCI for the feature is calculated to be 35, which is well below the "B" value of 50 for runways. According to guidelines in Figure 42, a major or overall repair is definitely needed. Several repair alternatives should be developed, and economic analysis should be conducted to select the most economical alternative.

TABLE 33. SUMMARY OF PAVEMENT DISTRESS PCI, AND $\overline{PCR}$ FOR RUNWAY AT FORT WAINWRIGHT

Distress Type	Sev. Level	Distress Density, Percent Slabs 1	2	3
2; Corner Break	L	25	20	5
	M	15	15	10
	H	5		
3; Long/Trans/ Diag. Crk.	L	20	5	5
	M		15	
	H	5	5	
5; Joint Seal Damage	L			✓
	M	✓		
	H			
6; Patching, Less than 5 ft^2	L			
	M			
	H	5		
7; Patching/ Utility Cut	L	10		35
	M			
	H			
10; Scaling/Map Crk/Crazing	L		20	
	M			
	H			
12; Shattered Slab	L	10	25	5
	M	5		
	H			
13; Shrinkage Crk.	L	35	25	45
	M			
	H			
14; Spalling, Joint	L			5
	M	5		
	H		5	
15; Spalling, Corner	L		5	
	M	5		
	H			
PCI		21	26	58

Ave. PCI for feature = 35

SECTION IX

SUMMARY, CONCLUSIONS, AND RECOMMENDATIONS

SUMMARY

A pavement condition index (PCI) for airfield pavements has been developed. The PCI, which is expressed as a numerical rating ranging from 0 to 100, provides a measure of airfield pavement structural integrity and surface operational condition. The PCI is calculated based on pavement distress types, severities, and densities measured during an inspection of the pavement. Distress types, descriptions, severity levels, and measurement criteria for jointed concrete and asphalt- or tar-surfaced pavements are presented in Volume II of this report. In order to obtain an accurate PCI, the recommendations of Volume II must be followed when conducting the pavement inspection.

The procedure for rating a pavement feature includes the following steps: (1) dividing it into sample units (a sample unit is approximately 20 slabs for jointed concrete pavements and 5000 square feet for asphalt- or tar-surfaced pavements); (2) inspecting each sample unit in the pavement feature; (3) calculating the PCI for each sample unit; and (4) averaging the PCIs of the sample units to obtain the overall PCI of the pavement feature.

The pavement rating procedures have been field-tested and validated on 123 pavement sections at nine airfields located in widely different environments and subjected to different traffic conditions. Preliminary guidelines for determining maintenance and repair (M&R) needs based on the PCI have also been developed.

CONCLUSIONS

The PCI is an accurate and objective tool for airfield pavement condition rating. The following conclusions are based on field testing and validating the PCI on over 100 pavement sections at nine airfields:

1. Evaluation of existing airfield pavement rating procedures indicates that they do not correlate well with ratings of experienced engineers.

2. The calculated PCI for a pavement feature agrees closely (or correlates highly) with the mean pavement condition rating ($\overline{PCR}$) obtained by averaging the individual ratings of a group of experienced pavement engineers.

3. The absolute mean difference between the PCI and $\overline{PCR}$ for all pavement sections was found to be 4.8 for jointed concrete pavements and 4.1 for asphalt- or tar-surfaced pavements. However, the average range between raters for the same pavement features was 11.3 for both types of pavements. Therefore, pavement condition rating based on PCI is much

more consistent than the individual subjective rating, since it is based on measured distress data and not on subjective judgment.

4. The base engineer's staff can determine the PCI, since the determination does not require special equipment. The only equipment needed to perform the pavement inspection is a measuring wheel (odometer), measurement scale, and a 10-foot straightedge (p 112). A certain amount of training is necessary, however.

5. To minimize inspection time and reduce cost, only a portion of the sample units of a pavement feature need be inspected. Use of the recommended guidelines for determining the number and location of sample units to be inspected will result in an adequate estimate of the PCI.

6. The PCI can be effectively used to determine maintenance and repair requirements.

7. The PCI measures pavement structural integrity and surface operational condition (localized roughness and safety) accurately and objectively; however, it does not directly measure structural capacity (for change in traffic mission), skid resistance, or long-wave roughness (over 50-foot waves). These items can only be measured by specialty teams and equipment provided by Headquarters U.S. Air Force Civil Engineering Center (HQUSAFCEC). The PCI, however, can be used to justify the need for in-depth pavement evaluation by USAFCEC evaluation teams.

8. The PCI provides the major commands with a common index for comparing the condition and performance of pavements at all operational bases within their jurisdictions. It also provides feedback on pavement performance for validation or improvement of current design procedures and maintenance practices.

9. The PCI provides a rational basis for assigning priorities for in-depth pavement evaluations by AFCEC specialty teams.

RECOMMENDATIONS

1. The airfield pavement condition rating procedure has been field-tested and verified and should be implemented on a trial basis. Successful implementation of the procedure will require training of personnel in pavement inspection and determination of the PCI; all needed manuals have been prepared and are ready for use.

2. The guidelines for determining maintenance and repair (M&R) needs based on the PCI should be further developed and field-tested.

3. Measurement of the PCI of a feature over a number of years would provide valuable data to analyze pavement performance and to determine the optimum time for performing needed M&R.

4. Procedures for determining the consequences of performing different M&R alternatives should be developed to enable engineers to conduct meaningful economic analysis to determine optimum alternatives.

5. An M&R requirement prediction, optimization, and priority system should be developed based on the PCI, skid resistance, long-wave roughness, and structural capacity.

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APPENDIX A

AIRFIELD PAVEMENT CONDITION SURVEY REPORT
(Proposed Revision of Chapter 3, AFR 93-5)

1. Scope
2. General
3. Basic Airfield Data
4. Jointed Concrete Pavement Condition Survey
5. Asphalt- or Tar-Surfaced Pavement Condition Survey
6. Condition Survey by Sampling
7. Airfield Pavement Condition Survey Reports
8. Distribution of Condition Survey Reports

1. Scope. This appendix describes the procedures for performing airfield pavement condition surveys and outlines the methods and data requirements for preparing condition survey reports.

2. General

a. The airfield pavement condition survey as accomplished by the base and major command civil engineer is the primary means of obtaining and recording vital airfield pavement performance data.

b. The condition survey for both jointed concrete and asphalt- or tar-surfaced airfield pavements consists of the following steps (Figure A-1):

(1) Each pavement feature is inspected, and existing distress types, severity levels, and densities are recorded. Volume II of this report has been prepared for use by the pavement engineer as a reference for performing the inspection. It is imperative that the engineer follow the guidelines in the manual when recording the distress data.

(2) A deduct value is determined from the appropriate curve for each distress type, density, and severity level.

(3) The total deduct value (TDV) is determined by summing all deduct values from each distress condition observed.

(4) The corrected deduct value (CDV) is determined based on the TDV and the number of distress conditions observed with individual deduct values greater than five points.

(5) The pavement condition index (PCI) is calculated as follows:

$$PCI = 100 - CDV$$

(6) The pavement condition rating is determined based on the PCI value according to the scale in Figure A-1 (excellent, very good, ... or failed).

c. The results of the condition survey are recorded and compiled into a precise report which supplements and updates the pavement data previously known about the airfield. The condition survey fulfills the following objectives:

(1) Indicates the present condition of the pavement in terms of structural integrity and operational surface condition.

(2) Provides the Base Civil Engineer with an objective and rational basis for determining maintenance and repair needs and priorities, and a warning system for early identification and/or projection of major repair requirements.

(3) Provides the major commands with a common index for comparing the condition and performance of pavements at all operational bases

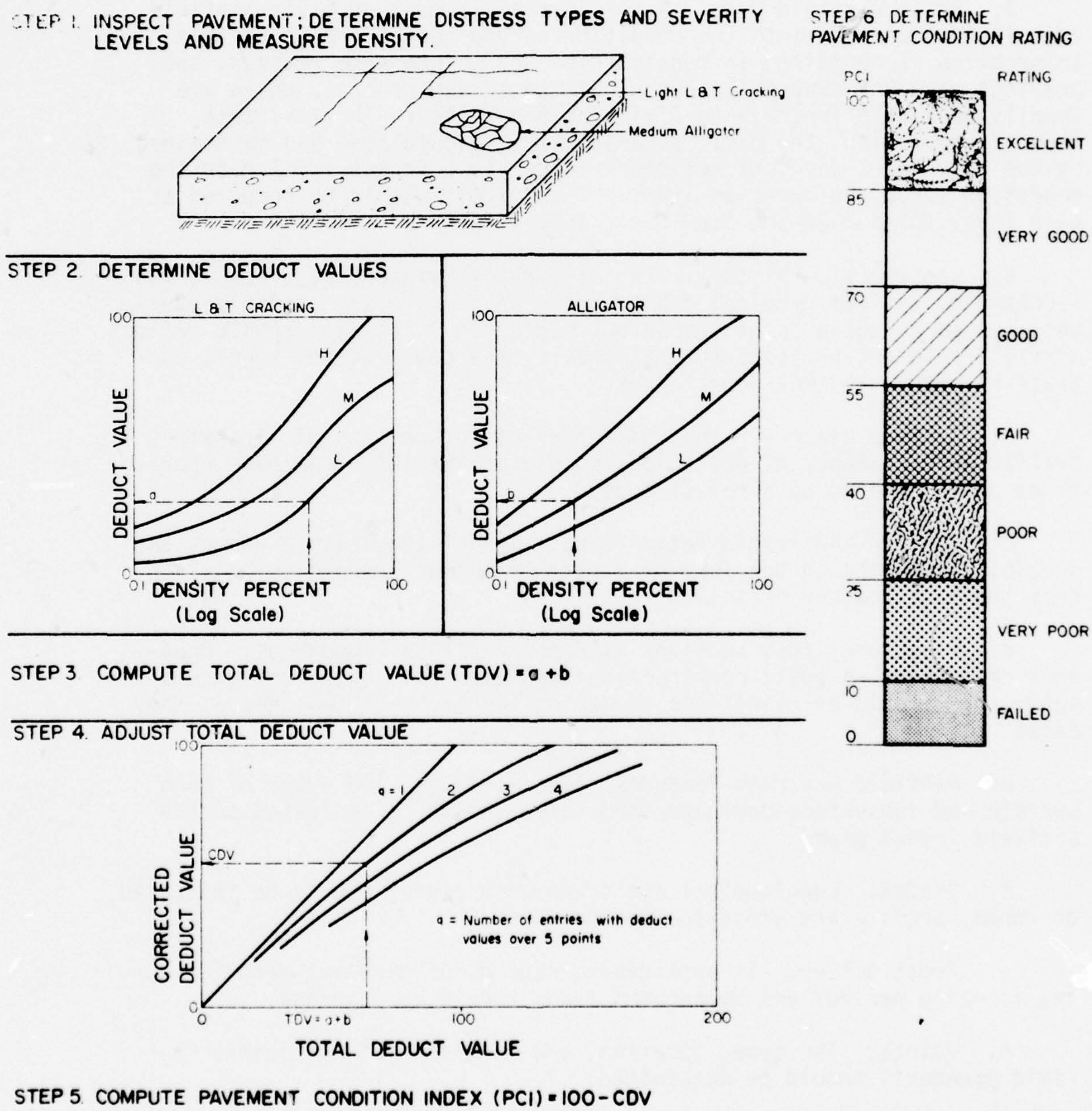


Figure A-1. Steps for Determining Airfield Pavement Condition Survey.

within their jurisdictions, and also provides a rational justification for major repair projects and for requesting in-depth pavement evaluation by the AFCEC.

(4) Provides HQ USAF with a rational basis for assigning priority for in-depth pavement evaluations by AFCEC specialty teams.

(5) Provides feedback on pavement performance for validation or improvement of current pavement procedures.

3. Basic Airfield Data. A considerable amount of basic airfield data is incorporated into the condition survey report. Most of this information is contained in construction and maintenance records, and previous pavement evaluation and condition survey reports, which are usually available in the Base Civil Engineer files. To facilitate report preparation, the basic data should be accumulated and maintained by the base-level pavement engineer-manager in a format similar to the condition survey information items. These items should be compiled at base level for subsequent use in the survey reports as follows:

a. Construction History. The history of maintenance, repair, and reconstruction from original construction of the primary airfield pavement system to the present should be maintained. The data should reflect airfield pavement projects accomplished by the construction agent, contract services, and BCE work forces.

b. Traffic History. The character and composition of aircraft traffic and frequency of operations should be obtained from base operations and tabulated by aircraft type.

c. Weather and Precipitation Data. Annual temperature ranges and precipitation data in the form of a weather summary should be obtained from the base weather office.

d. Plans and Cross Sections of Major Airfield Components. Drawings reflecting as-built construction supplement the construction history; they should be maintained to depict the pavement features as they exist.

e. Airfield Drainage Features. The locations and types of both surface and subsurface drainage structures should be indicated on the airfield layout plan.

f. Grades. Longitudinal and transverse grades should be indicated on runway profile and cross-section drawings.

g. Frost Action. If applicable, records of pavement behavior during freezing periods and subsequent thaws should be obtained.

h. Joints. The type, location, and condition of all joints in rigid pavements should be determined.

i. Photographs. Photographs depicting both general and specific airfield conditions are desirable.

j. Pavement Evaluation and Condition Survey Reports. All previous pavement evaluation and condition survey reports should be on hand and maintained in chronological order.

4. Jointed Concrete Pavement Condition Survey. The pavement must first be divided into "features" based on the pavement's design, construction history, and traffic area. A designated pavement feature therefore (1) has consistent structural thickness and materials, (2) was constructed at one time, and (3) is located in one traffic area. The features are outlined and identified on the airfield layout plan.

Each feature is divided into "sample units" of approximately 20 slabs; each sample unit is inspected individually, and its PCI is calculated. Figure A-2 illustrates division of a feature into sample units. Each sample unit is numbered so it can be relocated for future inspections, maintenance needs, or random sampling purposes.

The actual inspection is performed by walking over each slab of the sample unit and recording distress(es) existing in the slab on the jointed concrete pavements - condition survey data sheet for sample unit (Figure A-3). One data sheet is used for each section. A sketch is made of the sample unit using the dots as joint intersections. The appropriate number code for each distress found in the slab is placed in the square representing the slab. The letter L (low), M (medium), or H (high) is included along with the distress number code to indicate the severity level of the distress. For example, 15L indicates that low severity corner spalling exists in the slab.

Volume II of this report contains the types, descriptions, severity levels, and photographs of jointed concrete pavement distresses. This manual must be available to the pavement inspector to assist in distress identification. The manual also includes a detailed description of how to count the distresses in the individual slabs. When conducting the inspection, the inspector must follow the guidelines established in the distress identification manual very closely to obtain an accurate distress count.

From the distress count, a summary of the distresses and the severities of each distress contained in the sample unit is compiled on the survey data sheet. This summary is used to compute the PCI for the sample unit by following the steps presented in paragraph 2 of this appendix. Figure A-4 presents the deduct curves for each distress type and Figure A-5 gives the corrected deduct curve. Figure A-3 shows the summary of the distress densities and severities and the computed PCI for the sample unit.

One feature can be divided into two or more features based on distress condition during the survey. If the density, severity, and types of distress for a group of sample units differ greatly from those of the rest of the feature, these sample units can be separated into another feature if desired.

The PCIs for all the sample units are compiled into a summary, as shown in Figure A-6. The overall condition rating of the feature is

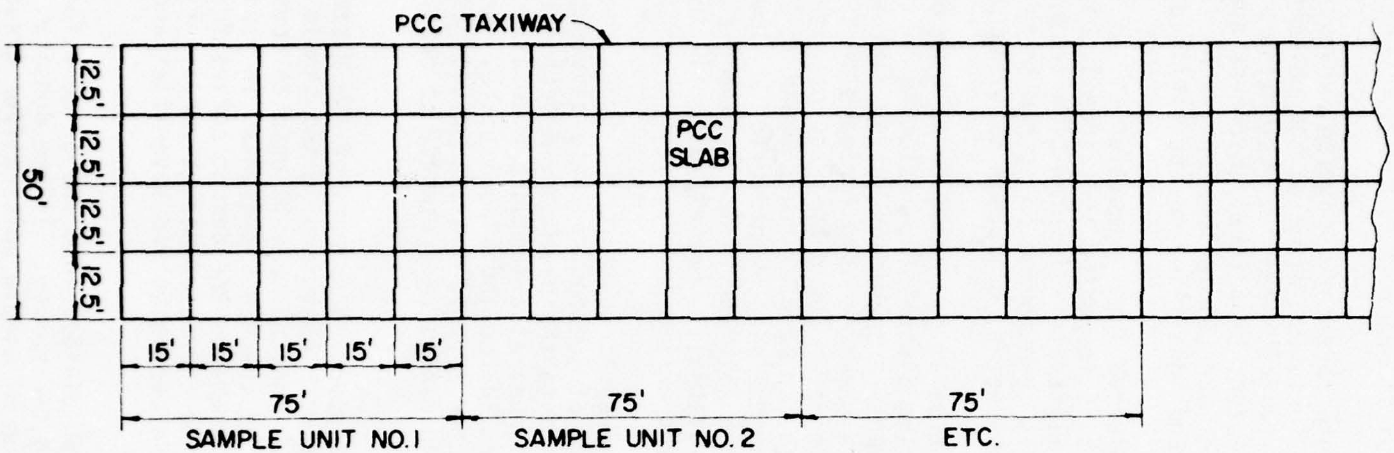


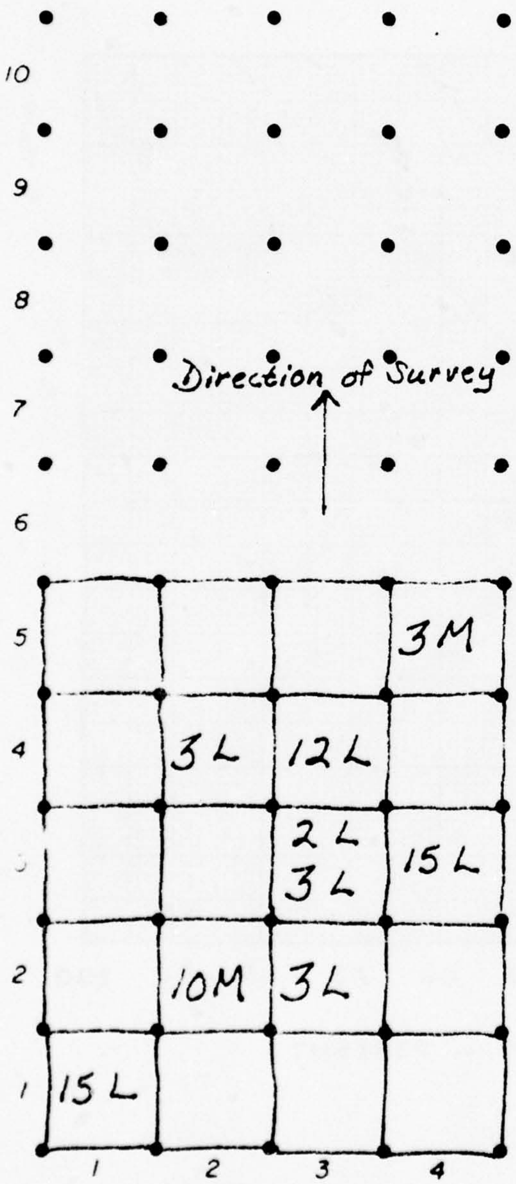
Figure A-2. Illustration of Division of a Jointed Concrete Pavement Feature Into Sample Units of 20 Slabs.

JOINTED CONCRETE PAVEMENT
CONDITION SURVEY DATA SHEET FOR SAMPLE UNIT

AIRFIELD Z FEATURE TW1

DATE 3/28/76 SAMPLE UNIT #1

SURVEYED BY MS/MD SLAB SIZE 12.5 X 15 ft
20 slabs



Distress Types

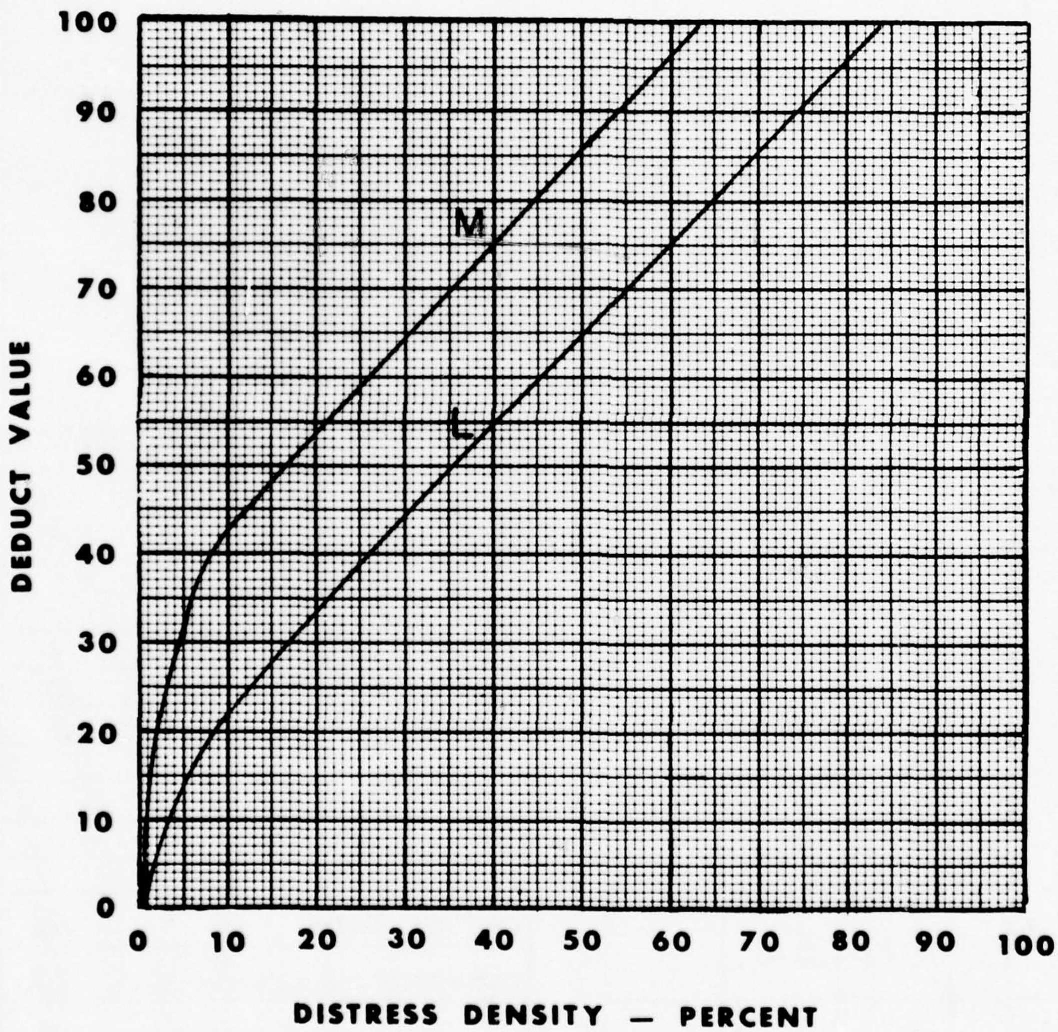
1. Blow-Up
2. Corner Break
3. Long/Trans/ Diag. Crk
4. "D" Crk
5. Joint Seal Damage
6. Patching, <5ft^2
7. Patching/Utility Cut
8. Popouts
9. Pumping
10. Scaling/Map Crk/Crazing
11. Settlement/ Fault
12. Shattered Slab
13. Shrinkage Crk
14. Spalling, Joints
15. Spalling, Corner

DIST. TYPE	SEV.	NO. SLABS	% SLABS	DEDUCT VALUE
2	L	1	5	4
3	L	3	15	11
3	M	1	5	11
10	M	1	5	7
12	L	1	5	10
15	L	2	10	3
DEDUCT TOTAL				46
CORRECTED DEDUCT VALUE (CDV) q=4				32

PCI = 100 − CDV = 68
RATING = GOOD

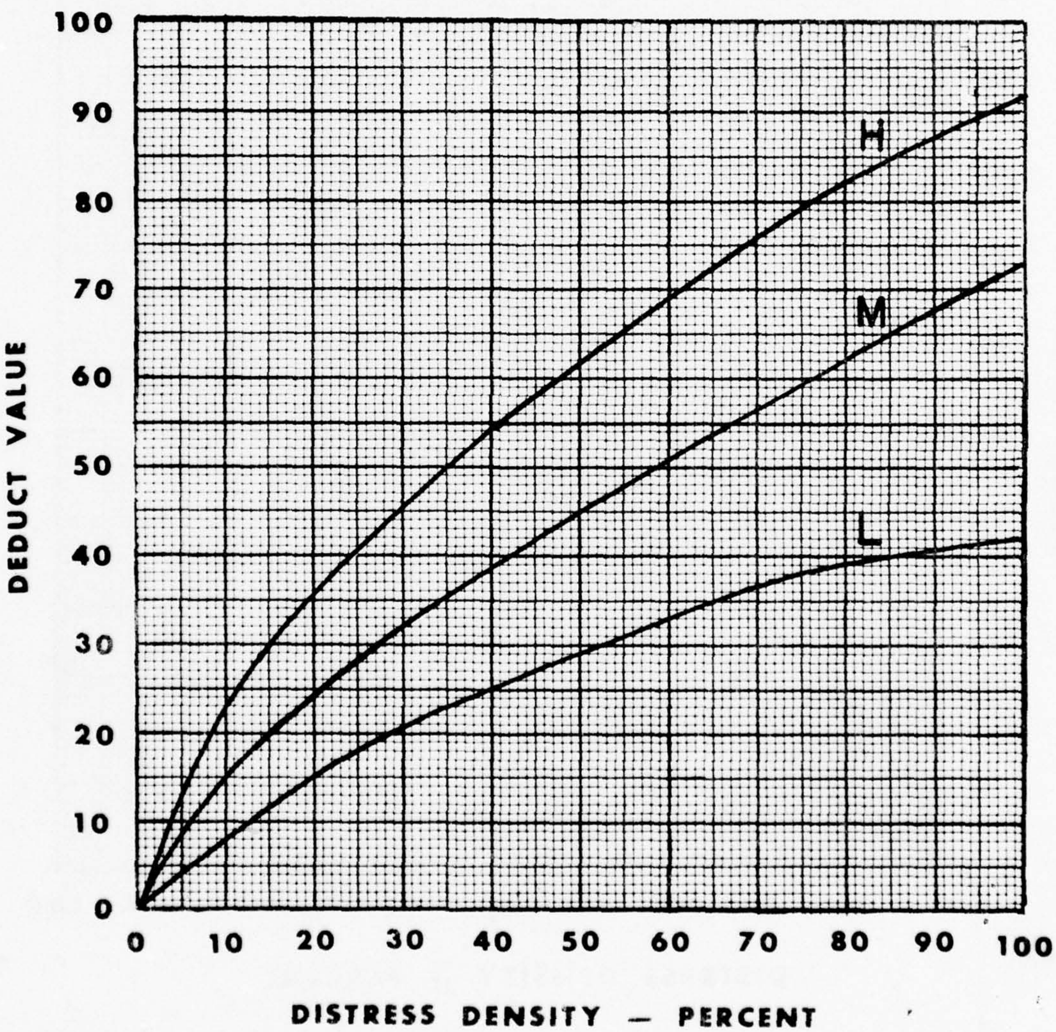
Figure A-3. Jointed Concrete Pavements - Condition Survey Data Sheet.

NOTE: High severity blow-up renders the pavement inoperative, therefore a deduct value of 100 should be used regardless of density.



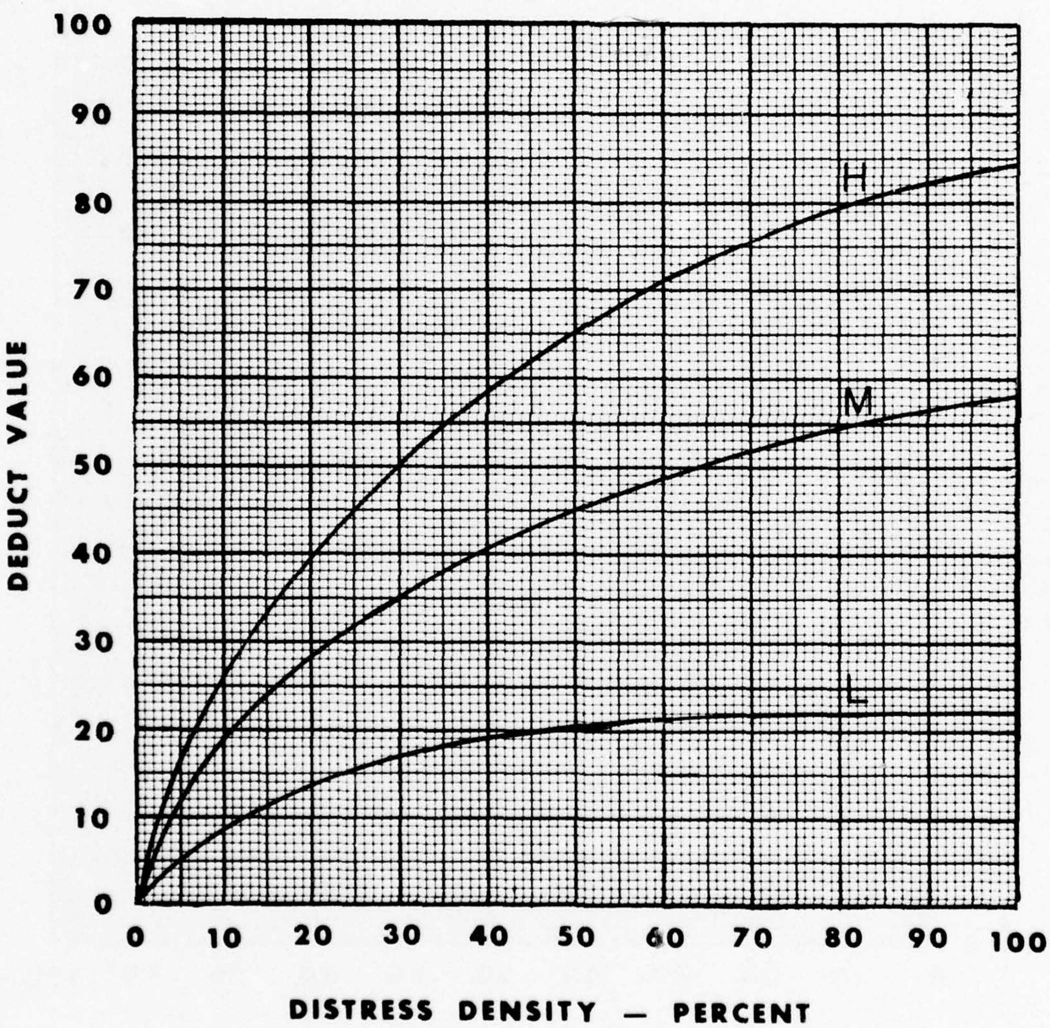
1. Blow-up.

Fgure A-4. Jointed Concrete Distress Deduct Values.



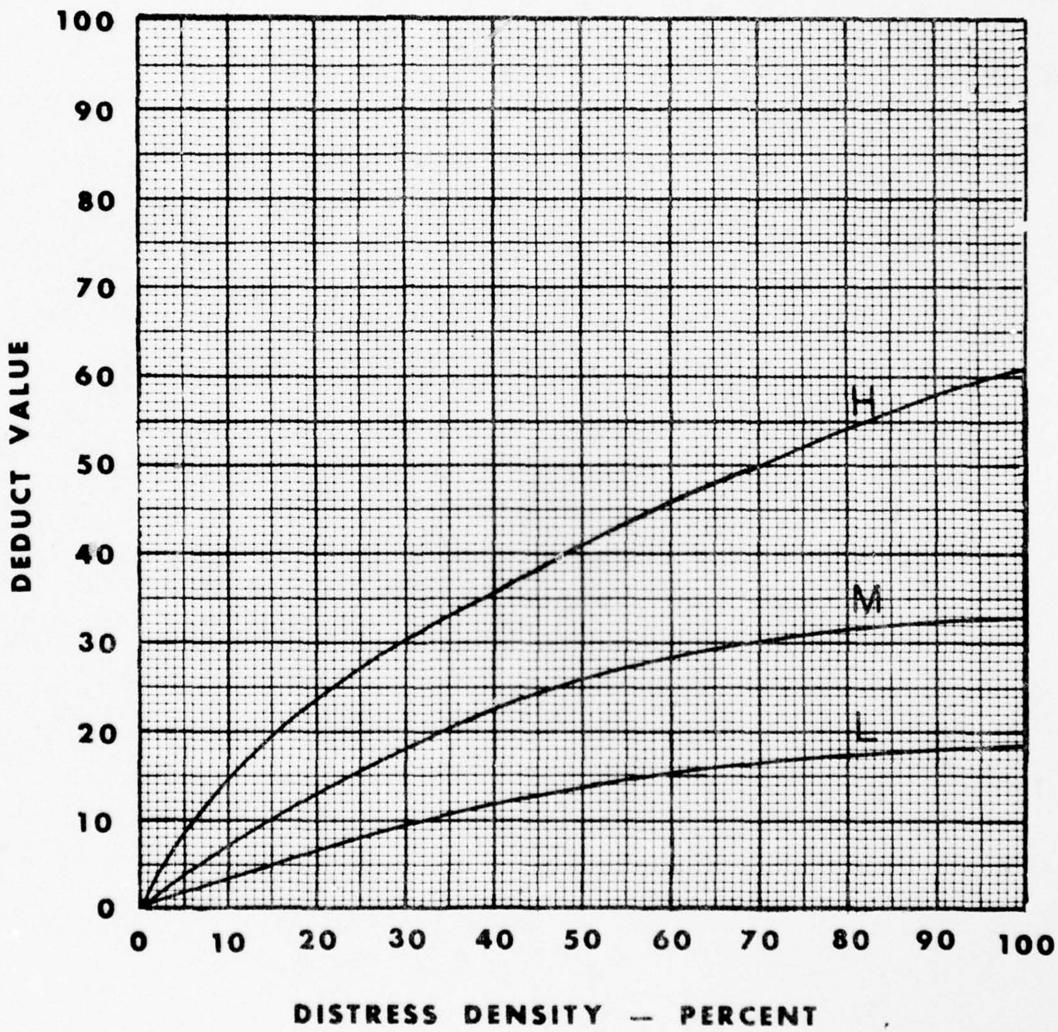
2. Corner break.

Figure A-4. Jointed Concrete Distress Deduct Values (continued).



3. Longitudinal/transverse/diagonal cracking.

Figure A-4. Jointed Concrete Distress Deduct Values (continued).



4. Durability cracking.

Figure A-4. Jointed Concrete Distress Deduct Values (continued).

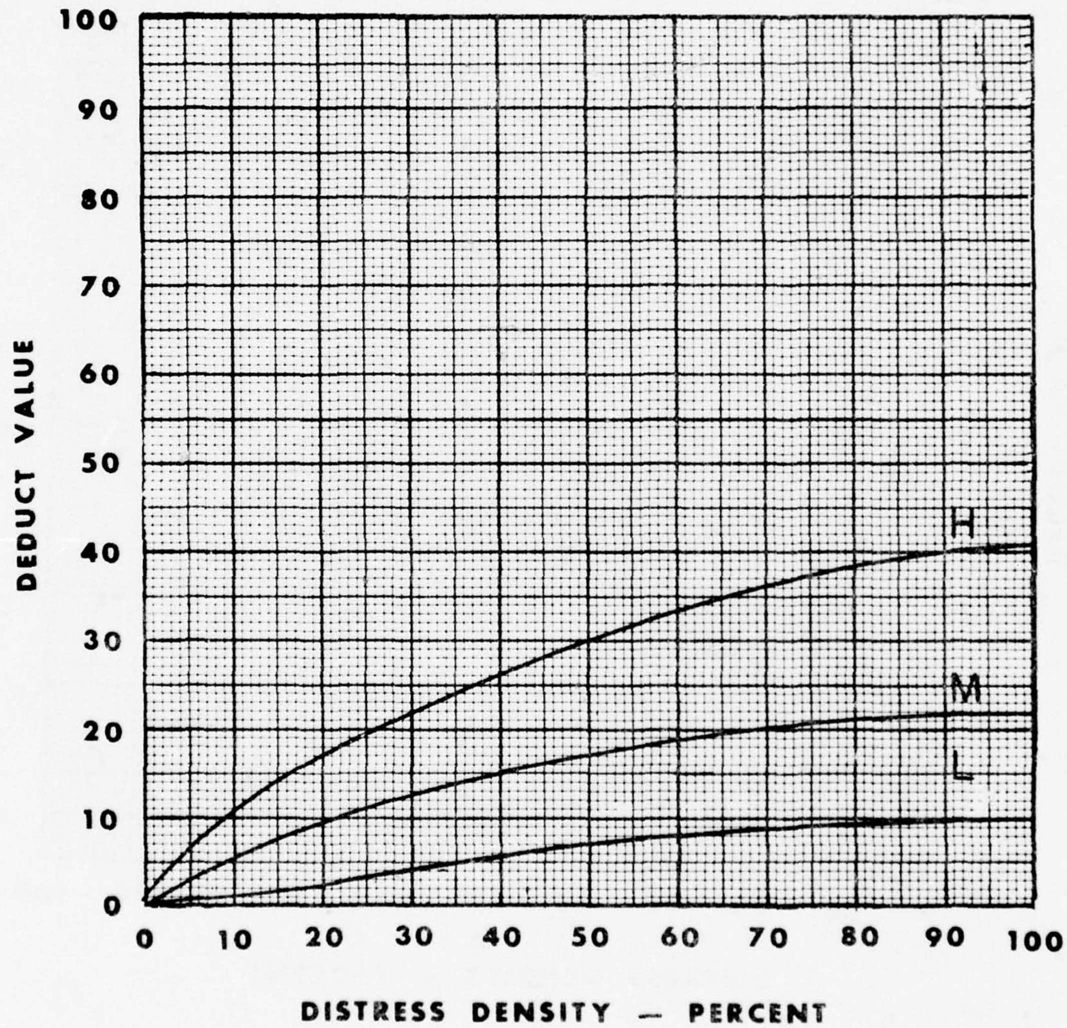
Joint seal damage is not rated by density. The severity of the distress is determined by the sealant's overall condition for particular section.

The deduct values for the three levels of severity are as follows:

1. High severity - 12 points
2. Medium severity - 7 points
3. Low severity - 2 points

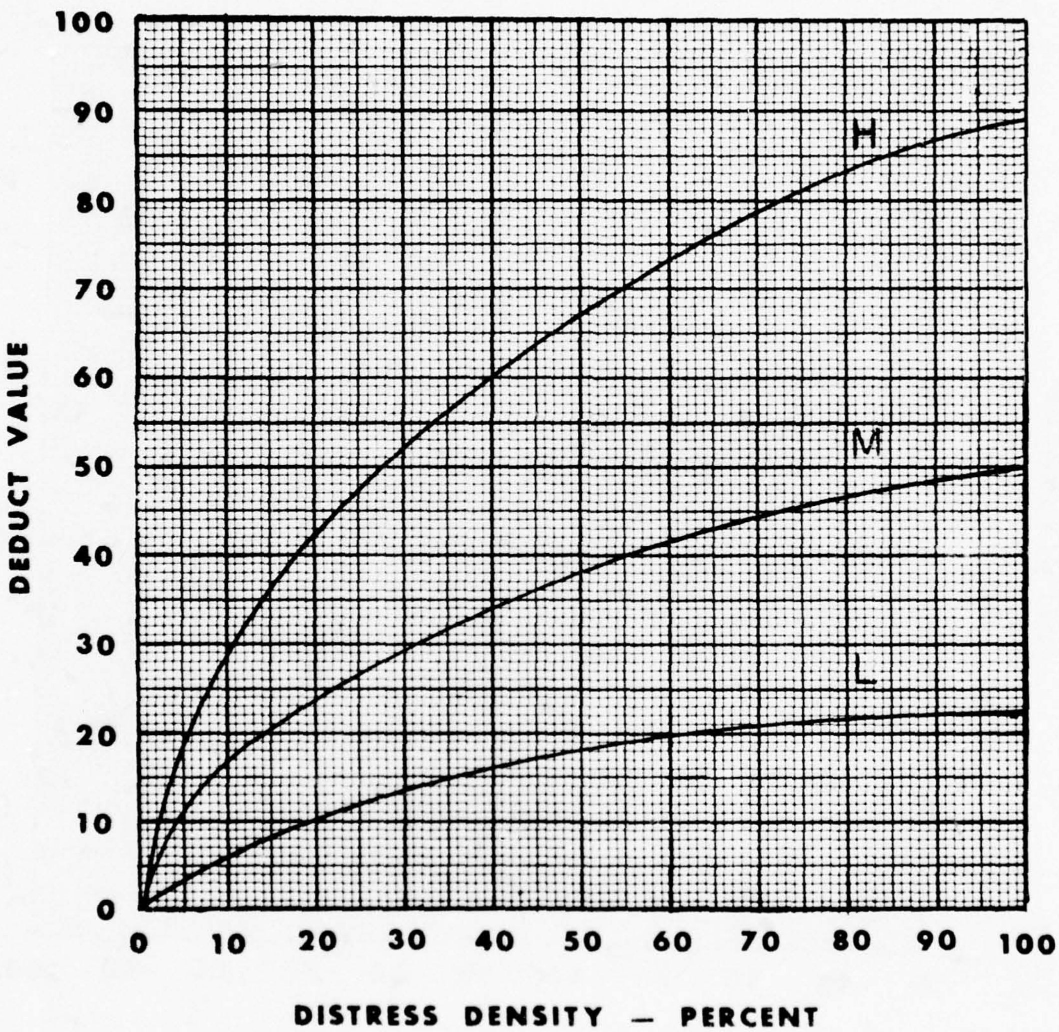
5. Joint seal damage.

Figure A-4. Jointed Concrete Distress Deduct Values (continued).



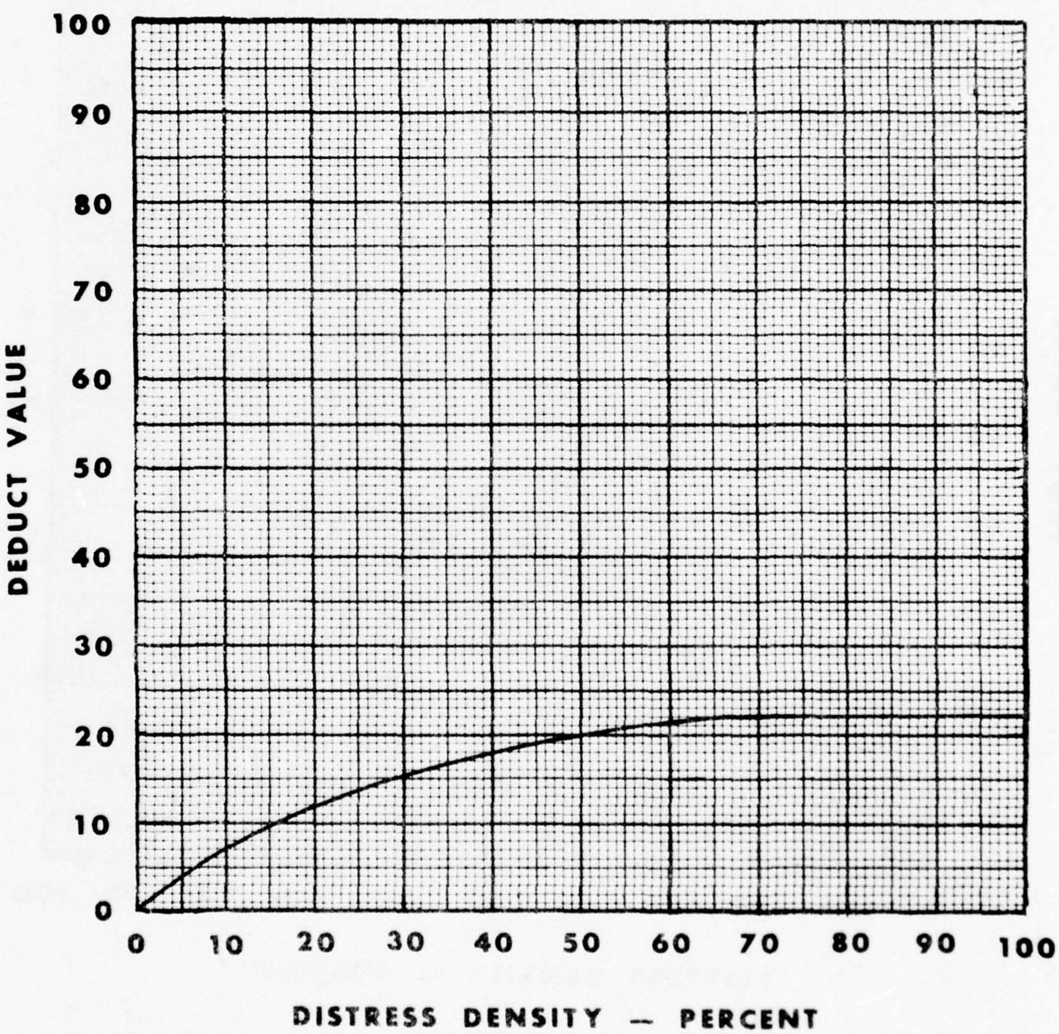
6. Small patch.

Figure A-4. Jointed Concrete Distress Deduct Values (continued).



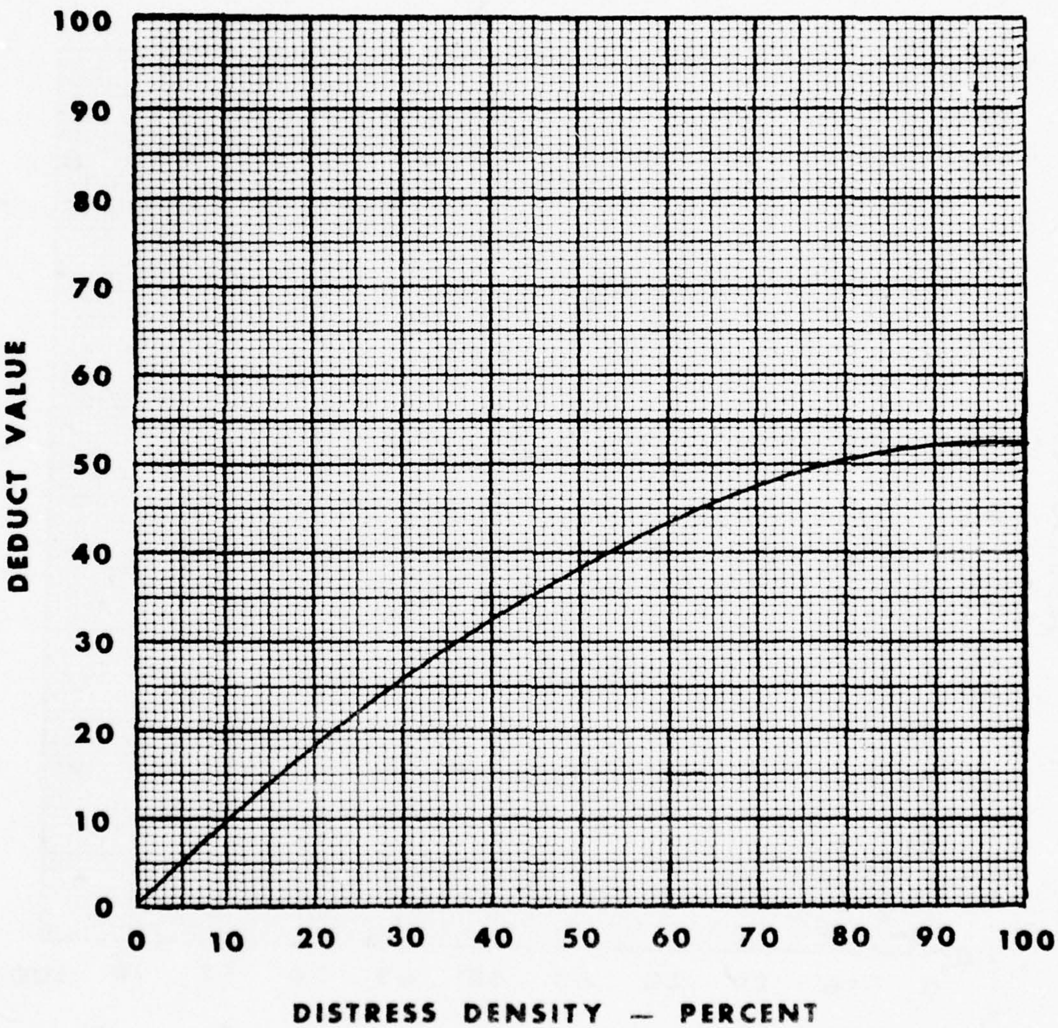
7. Patching/utility cut defect.

Figure A-4. Jointed Concrete Distress Deduct Values (continued).



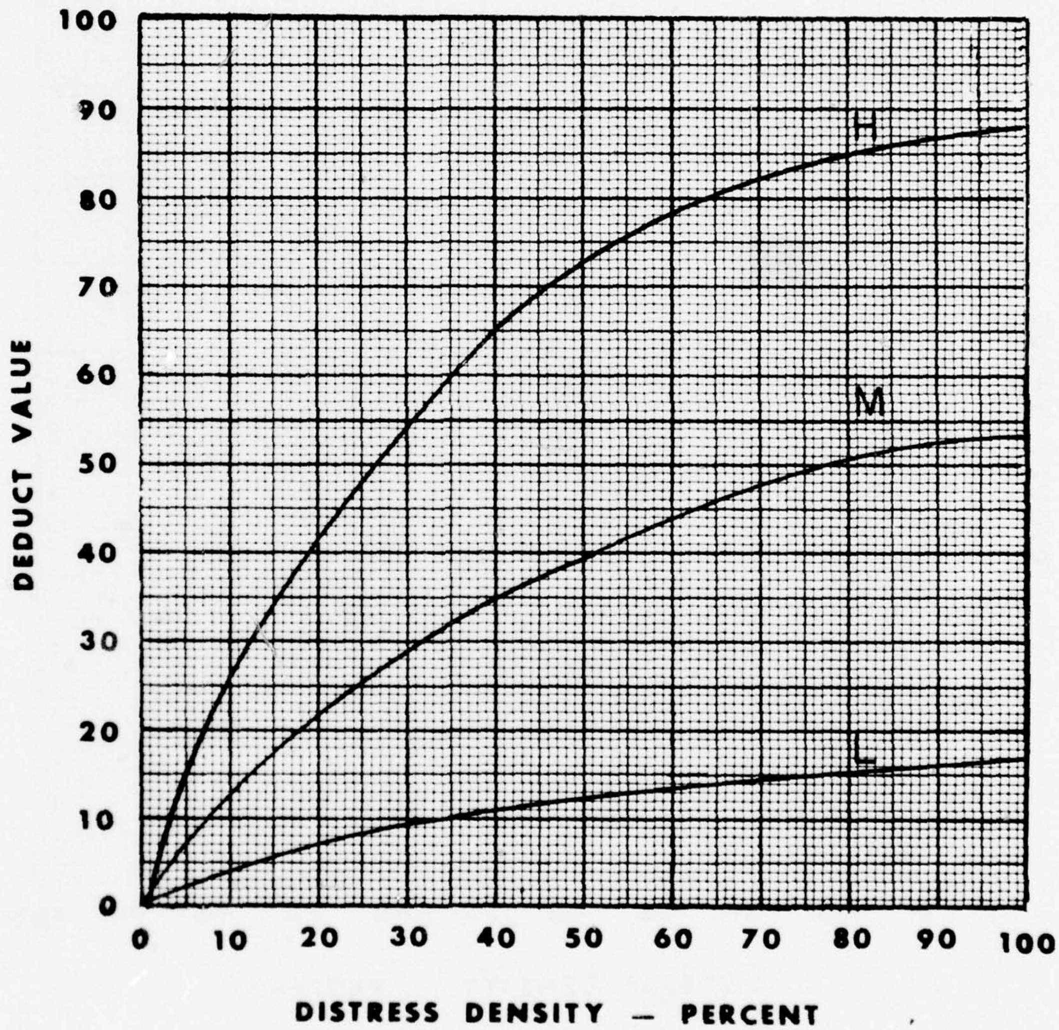
8. Popouts.

Figure A-4. Jointed Concrete Distress Deduct Values (continued).



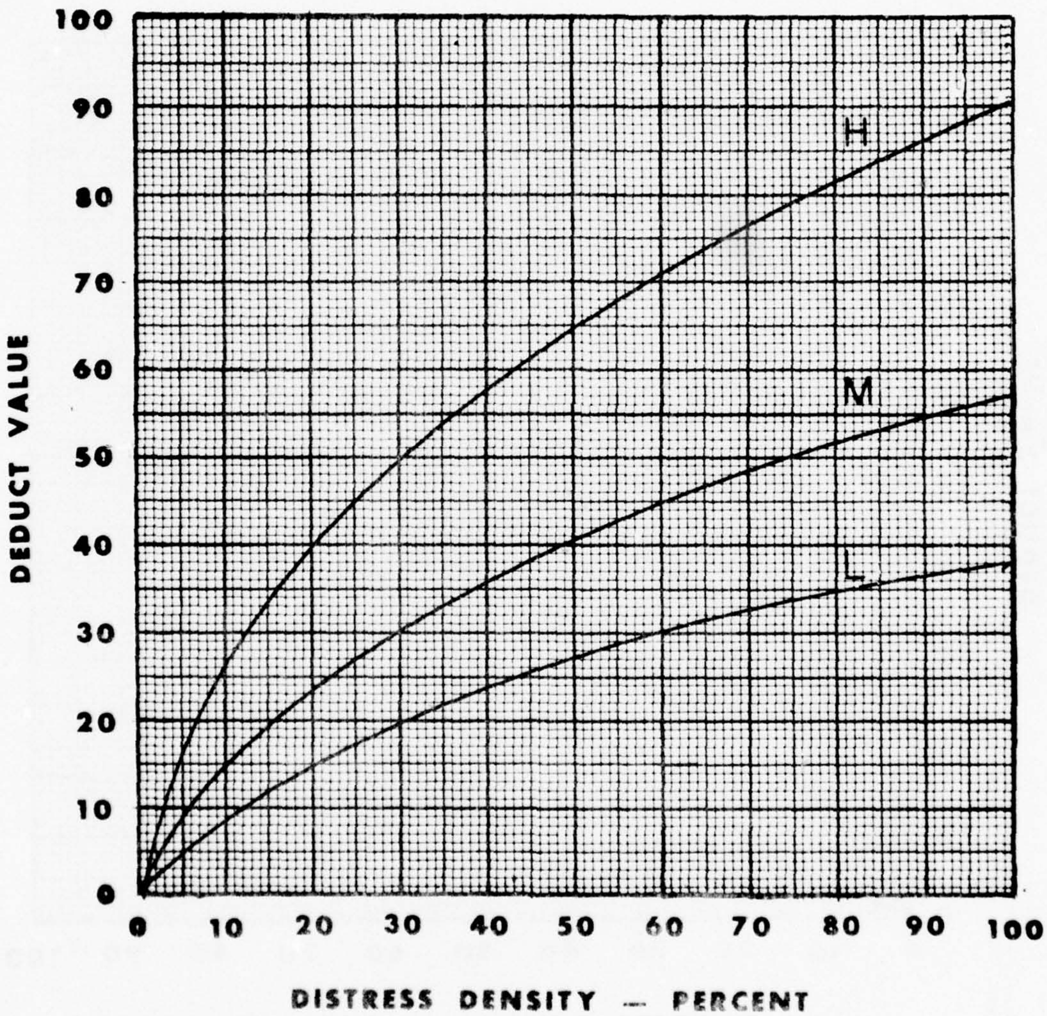
9. Pumping.

Figure A-4. Jointed Concrete Distress Deduct Values (continued).



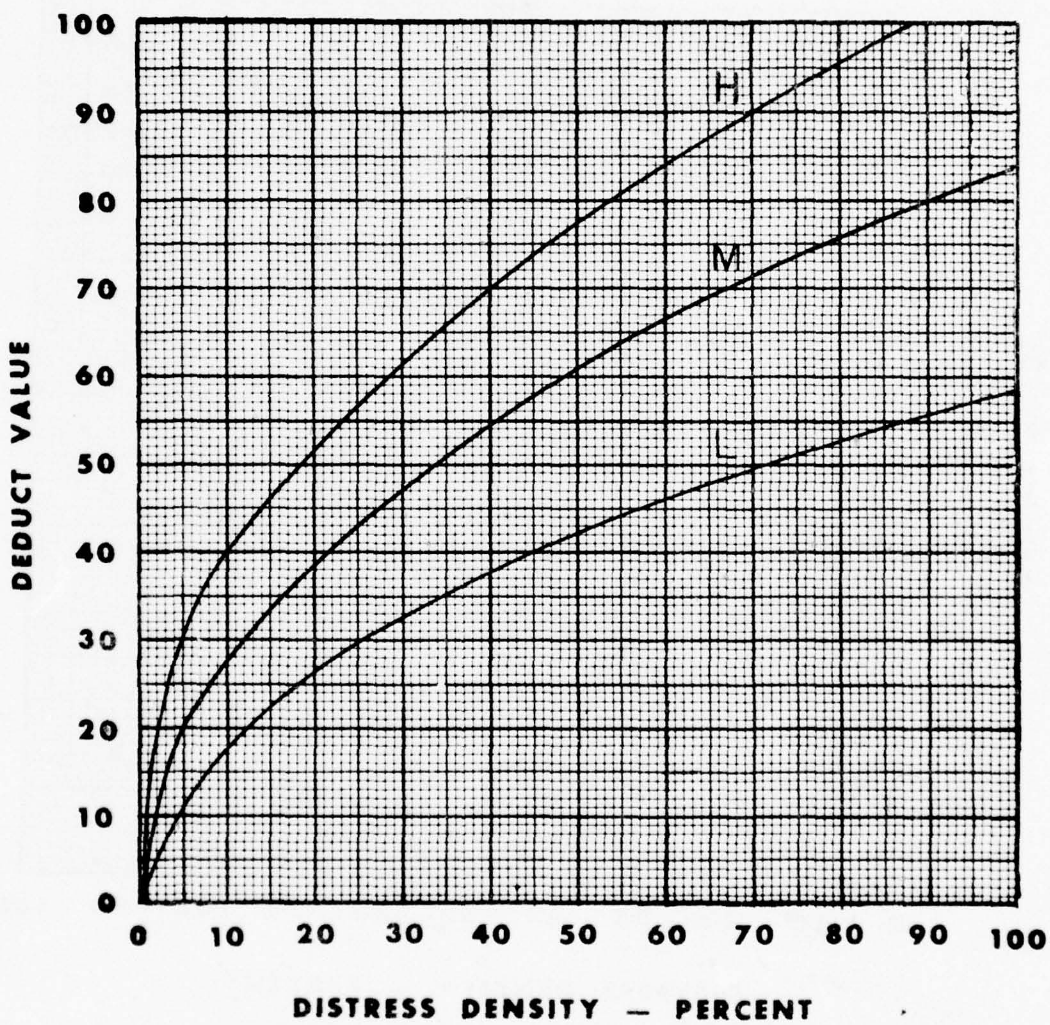
10. Scaling.

Figure A-4. Jointed Concrete Distress Deduct Values (continued).



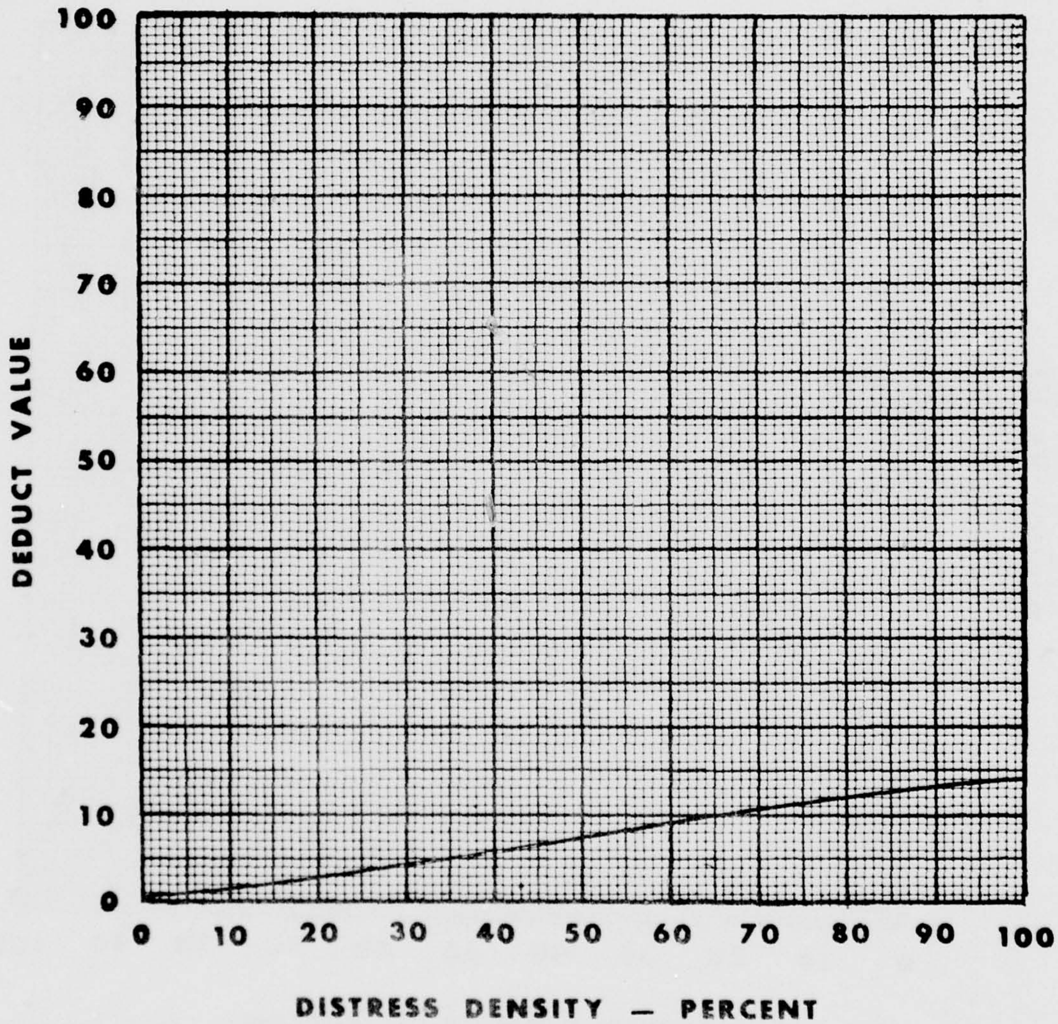
11. Settlement.

Figure A-4. Jointed Concrete Distress Deduct Values (continued).



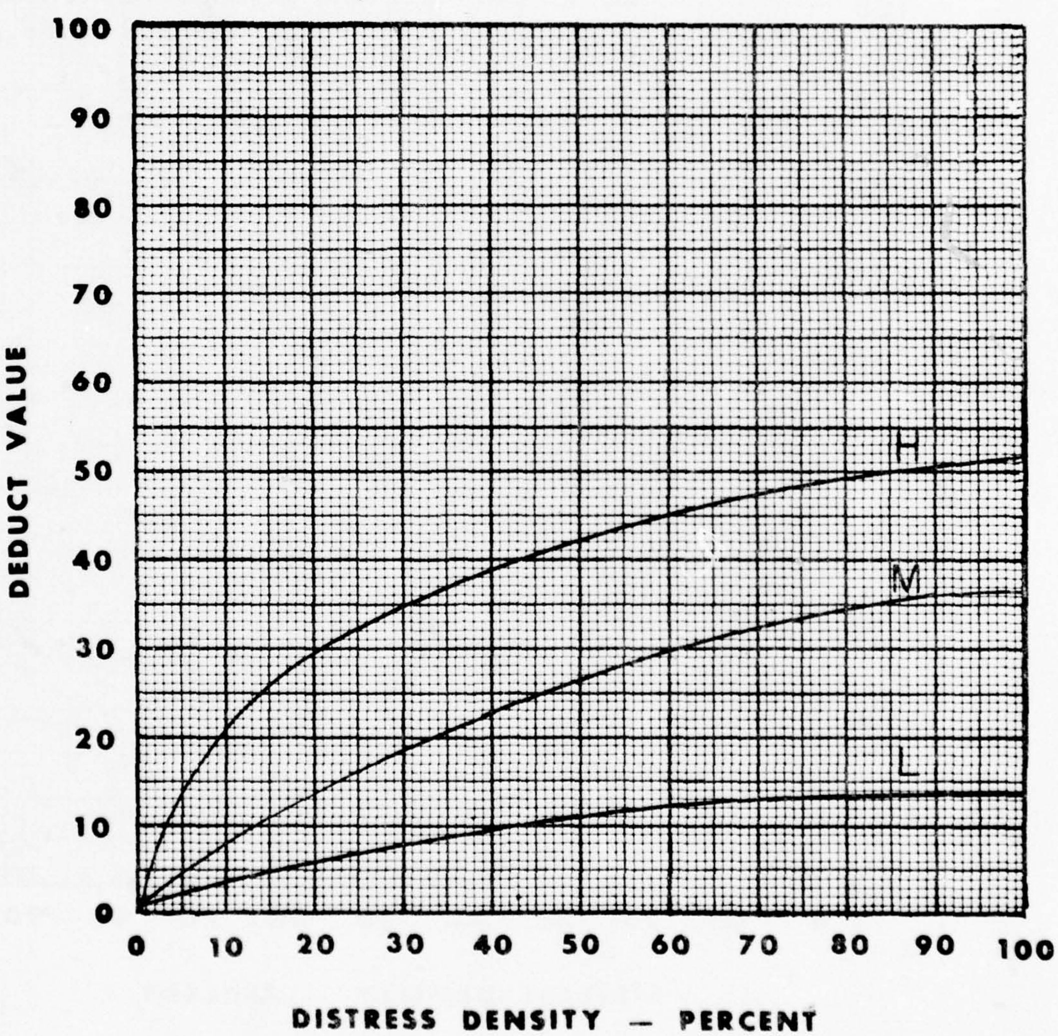
12. Shattered slab.

Figure A-4. Jointed Concrete Distress Deduct Values (continued).



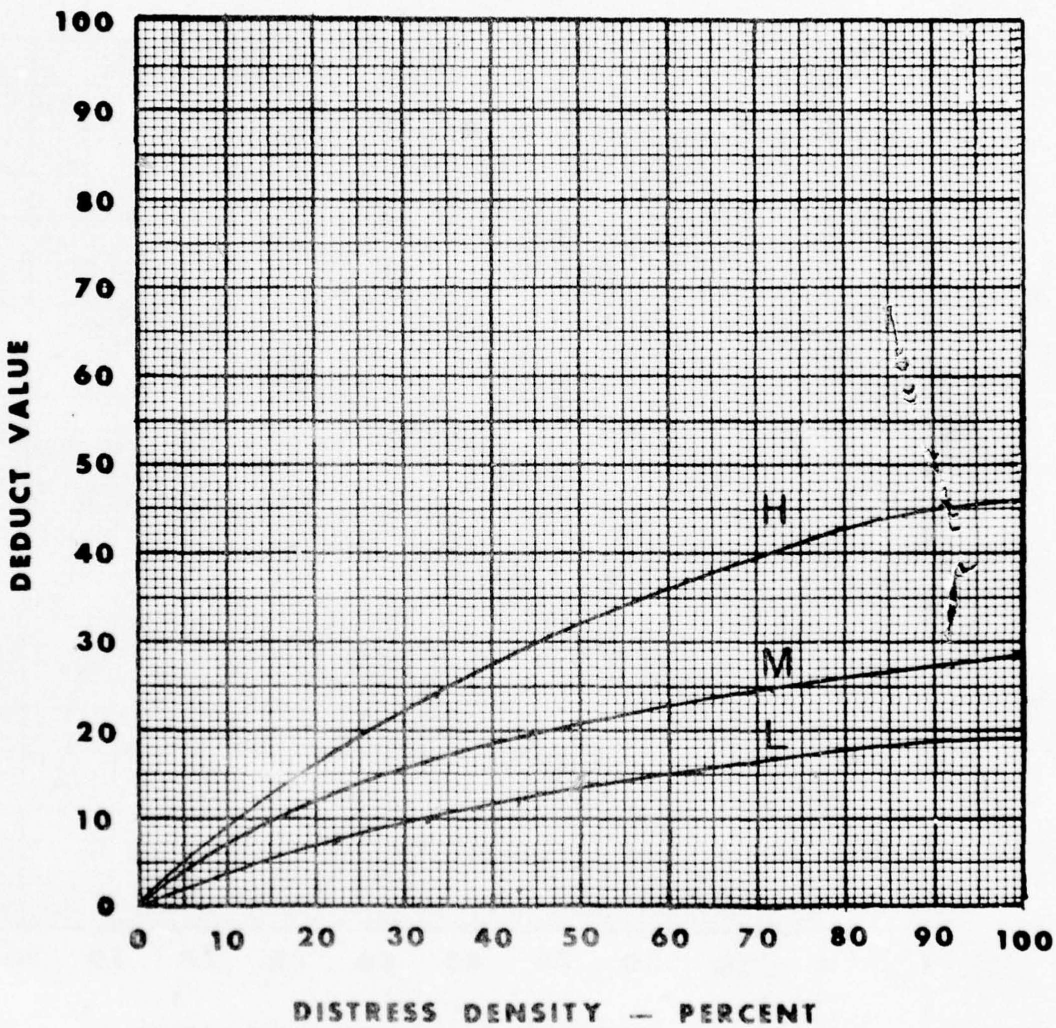
13. Shrinkage cracks.

Figure A-4. Jointed Concrete Distress Deduct Values (continued).



14. Spalling along the joints.

Figure A-4. Jointed Concrete Distress Deduct Values (continued).



15. Spalling corner.

Figure A-4. Jointed Concrete Distress Deduct Values (concluded).

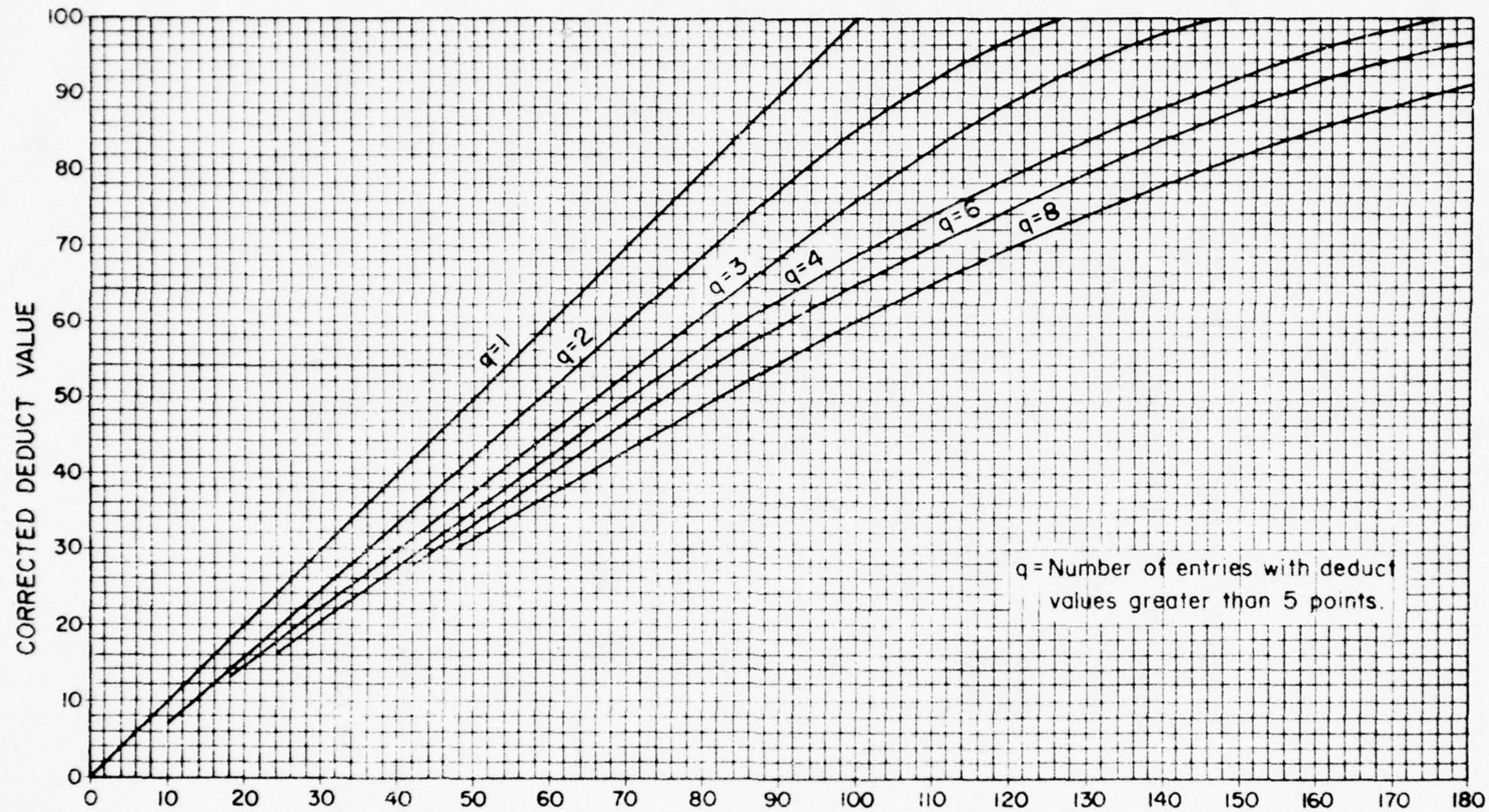


Figure A-5. Corrected Deduct Values for Jointed Concrete Pavements.

Pavement Feature: Taxiway 1

Total No. of Units: 5

Date of Survey: 3/28/76

Unit No.	No. of Slabs	Slab Size	PCI	Unit No.	No. of Slabs	Slab Size	PCI
1	20	12.5x15	60				
2	20	12.5x15	64				
3	20	12.5x15	74				
4	20	12.5x15	74				
5	20	12.5x15	28				

Average PCI for feature: 60

Condition rating: Good

Figure A-6. Feature Summary - Jointed Concrete Pavement.

determined by averaging the PCIs from each sample unit. It is important that each sample unit be identified adequately so that it can be located for future inspections. A plot of PCI values against time can be developed to assist in determining maintenance and repair needs.

5. Asphalt- or Tar-Surfaced Pavement Condition Survey. The pavement must first be divided into "features" based on the pavement's design, construction history, and traffic area. A designated pavement feature therefore (1) has consistent structural thickness and materials, (2) was constructed at one time, and (3) is located in one traffic area. The features are outlined and identified on the airfield layout plan.

Each feature is divided into "sample units" having surface area of approximately 5000 square feet (such as 50 x 100 feet). This division will provide a convenient grid system for reference when inspecting the feature. Each sample unit is inspected individually and its PCI is calculated. Figure A-7 shows an example of dividing a feature into sample units. Each sample unit is numbered so it can be relocated for future inspections, maintenance needs, or random sampling purposes.

Each sample unit of the feature is inspected. The distress inspection is conducted by walking over the sample unit, measuring each distress type and severity, and recording the data on the asphalt- or tar-surfaced pavements-condition survey data sheet for sample unit (Figure A-8). One data sheet is used for each sample unit. A hand odometer is very helpful in measuring the distress lengths and areas. A 10-foot straightedge and 12-inch scale must be available for measuring depth of ruts or depressions. Each column on the data sheet is used to represent a distress type, and the amount and severity of each distress located are listed in the column. For example, distress No. 5 (depression) is recorded as 6x4L, which indicates that the depression is 6 feet by 4 feet and of low severity. Distress type No. 7 (longitudinal and transverse cracking) is measured in linear feet; thus 10L indicates 10 feet of light cracking, 5M indicates 5 feet of medium cracking, etc. This format is very convenient for recording data in the field.

The total distress data are used to compute the PCI for the sample unit by following the steps presented in paragraph 2 of this appendix. Figure A-9 gives the deduct curves for each distress type, and Figure A-10 presents the corrected deduct curve. A summary of the distress densities and severities and the computed PCI for the sample unit are given in Figure A-8.

One feature can be divided into two or more features based on distress condition during the survey. If the density, severity, and types of distress for a group of sample units in the feature greatly differ from those of the rest of the feature, these sample units may be separated into another feature.

The PCIs for each sample unit are compiled into a summary as shown in Figure A-11. It is important that each sample unit be identified adequately so that it can be located for future inspections, maintenance needs, or random sampling purposes. A plot of PCI values against time can be developed to assist in determining maintenance and repair needs.

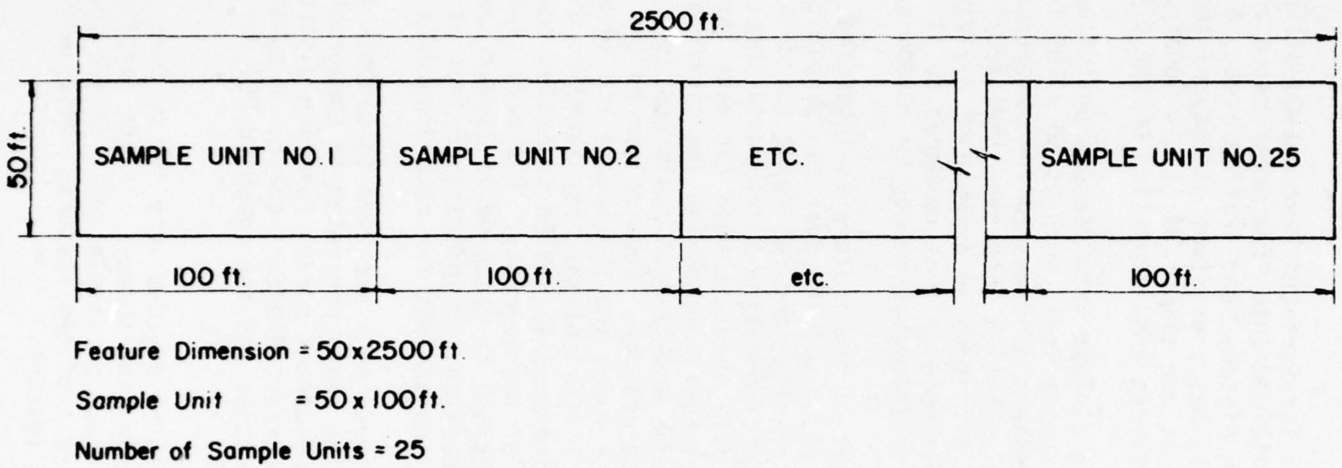


Figure A-7. Example Division of Asphalt- or Tar-Surfaced Pavement Feature Into Sample Units.

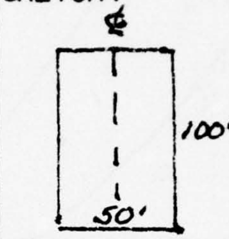
ASPHALT OR TAR SURFACED PAVEMENT
CONDITION SURVEY DATA SHEET FOR SAMPLE UNIT

AIRFIELD A FEATURE T5
DATE 6/8/76 SAMPLE UNIT 1
SURVEYED BY MD/MS/SK AREA OF SAMPLE 5000 sq ft

Distress Types

1. Alligator Cracking
2. Bleeding
3. Block Cracking
4. Corrugation
5. Depression
6. Jet Blast
7. Jt. Reflection (PCC)
8. Long. & Trans. Cracking
9. Oil Spillage
10. Patching
11. Polished Aggregate
12. Raveling/Weathering
13. Rutting
14. Shoving from PCC
15. Slippage Cracking
16. Swell

SKETCH:



EXISTING DISTRESS TYPES

	1	5	8	12		
	4 x 4 M	6 x 4 L	10 L	3 x 10 M		
	2 x 3 L		5 L			
			15 L			
			5 M			
			10 L			
			5 M			
TOTAL SEVERITY L	6 sq ft	24 sq ft	40 ft			
TOTAL SEVERITY M	16 sq ft		10 ft	30 sq ft		
TOTAL SEVERITY H						

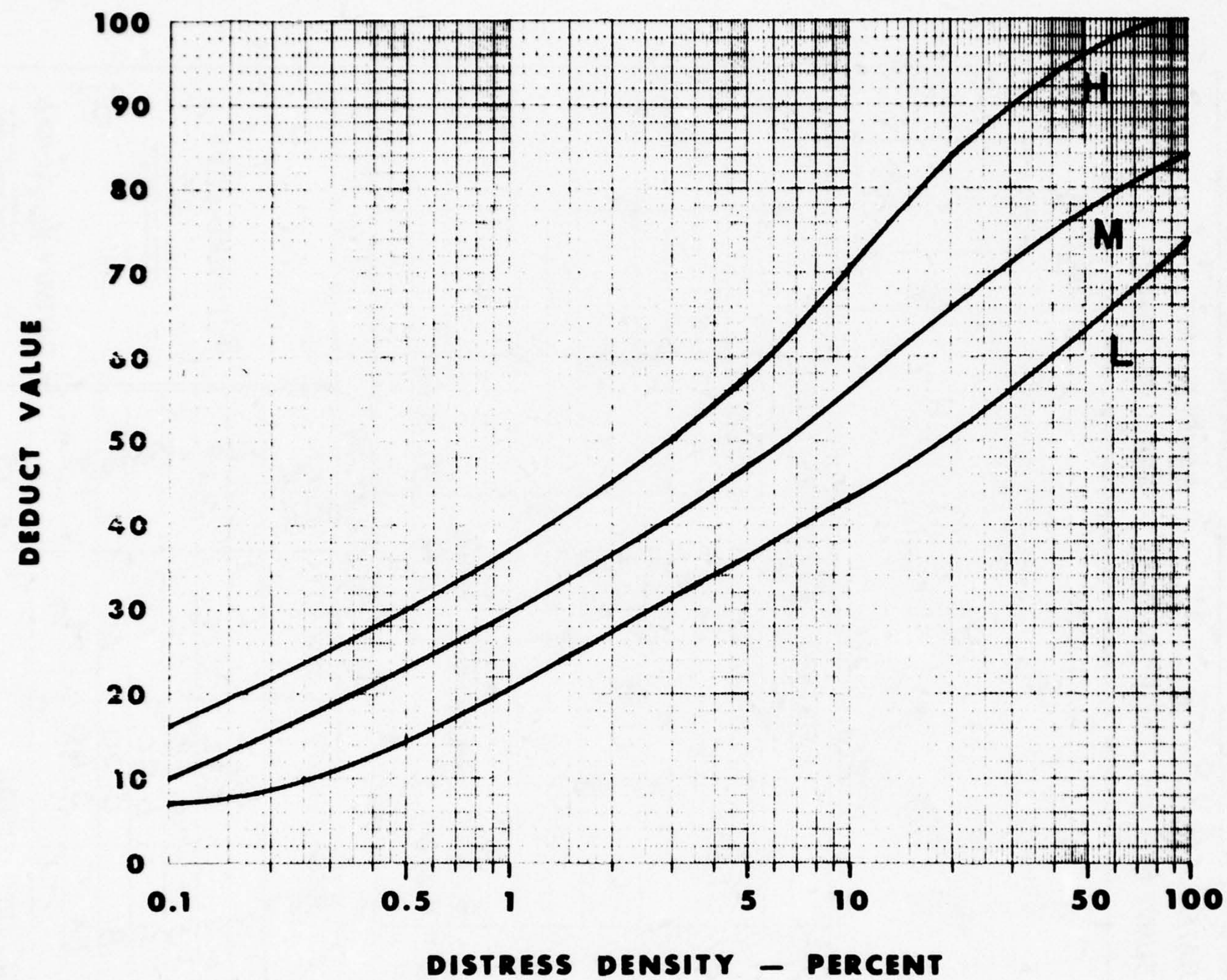
PCI CALCULATION

DISTRESS TYPE	DENSITY	SEVERITY	DEDUCT VALUE
1	0.12	L	7
1	0.32	M	19
5	0.48	L	2
8	0.80	L	5
8	0.20	M	5
12	0.60	M	7
DEDUCT TOTAL			45
CORRECTED DEDUCT VALUE (CDV)			25

PCI = 100 - CDV = 75

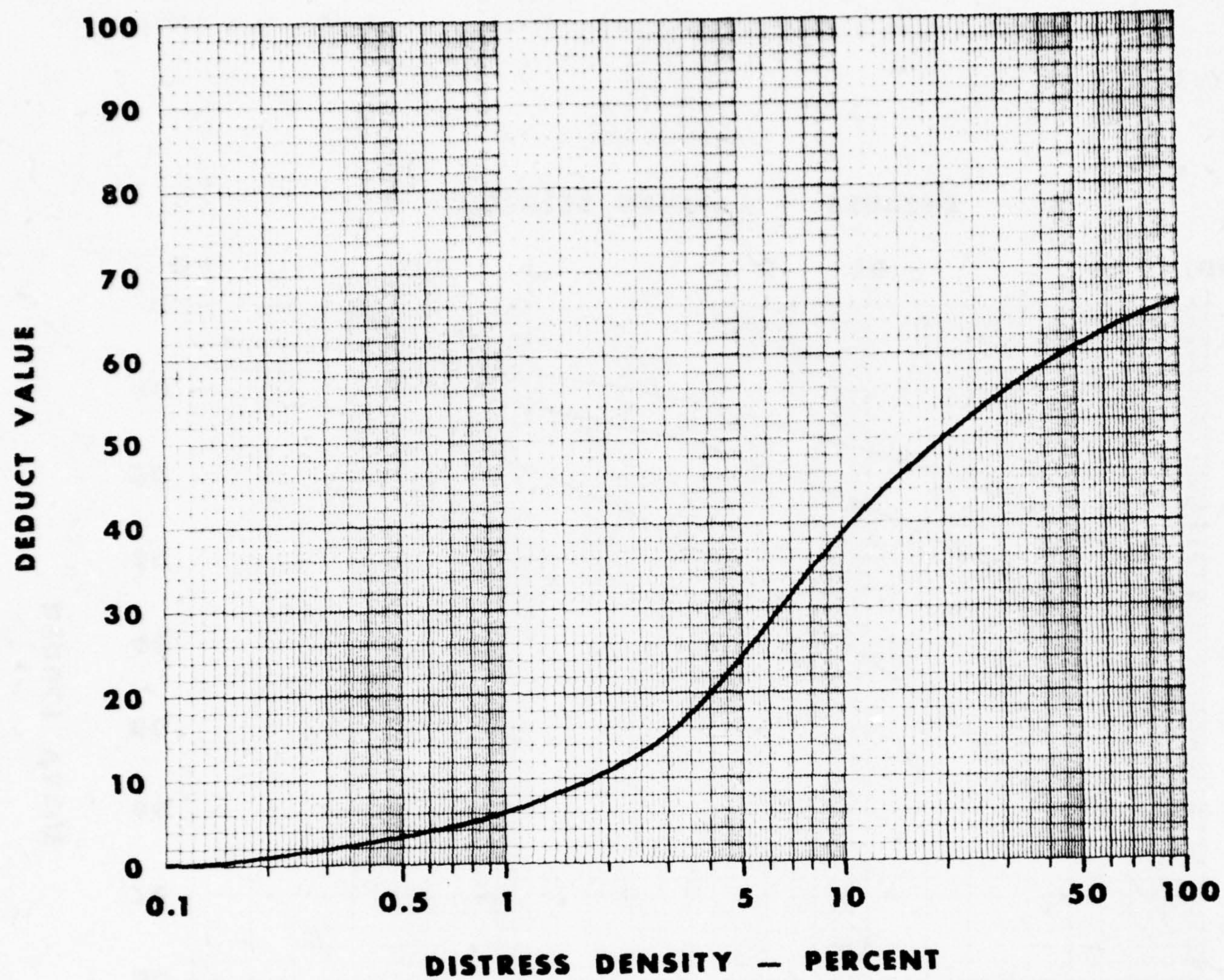
RATING = Very Good

Figure A-8. Asphalt- or Tar-Surfaced Pavements - Condition Survey Data Sheet.



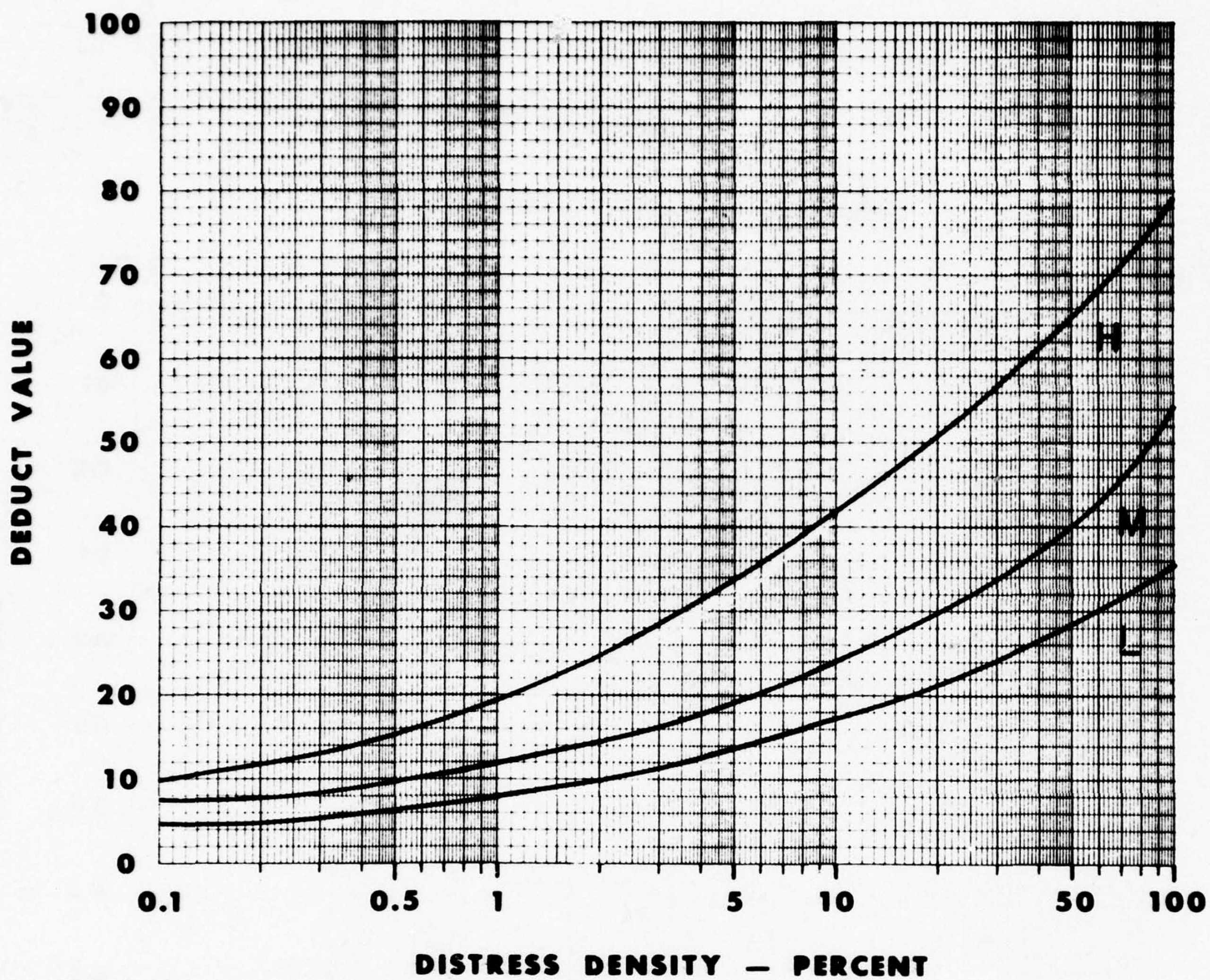
1. Alligator cracking.

Figure A-9. Asphalt- or Tar-Surfaced Pavement Deduct Values.



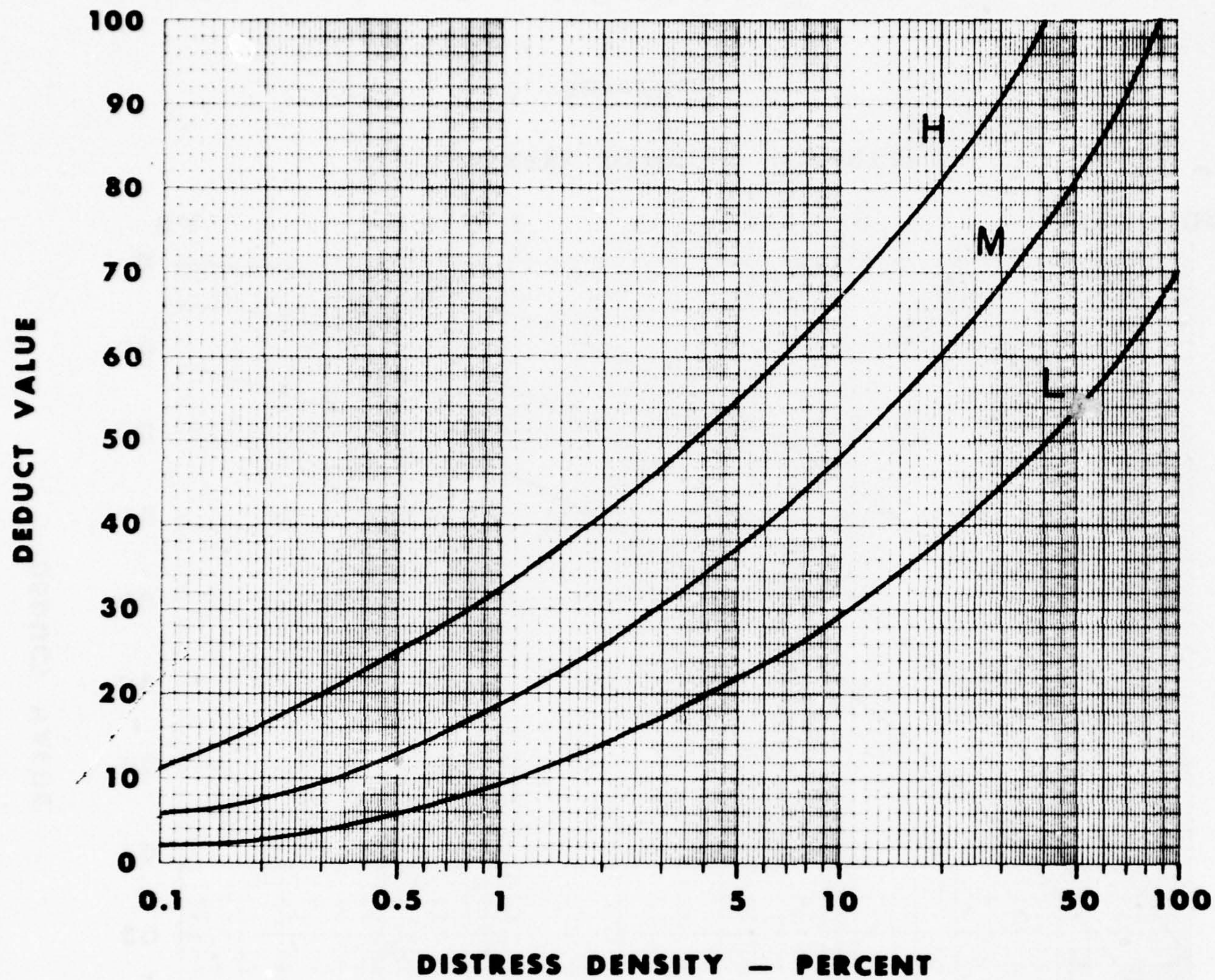
2. Bleeding.

Figure A-9. Asphalt- or Tar-Surfaced Pavement Deduct Values (continued).



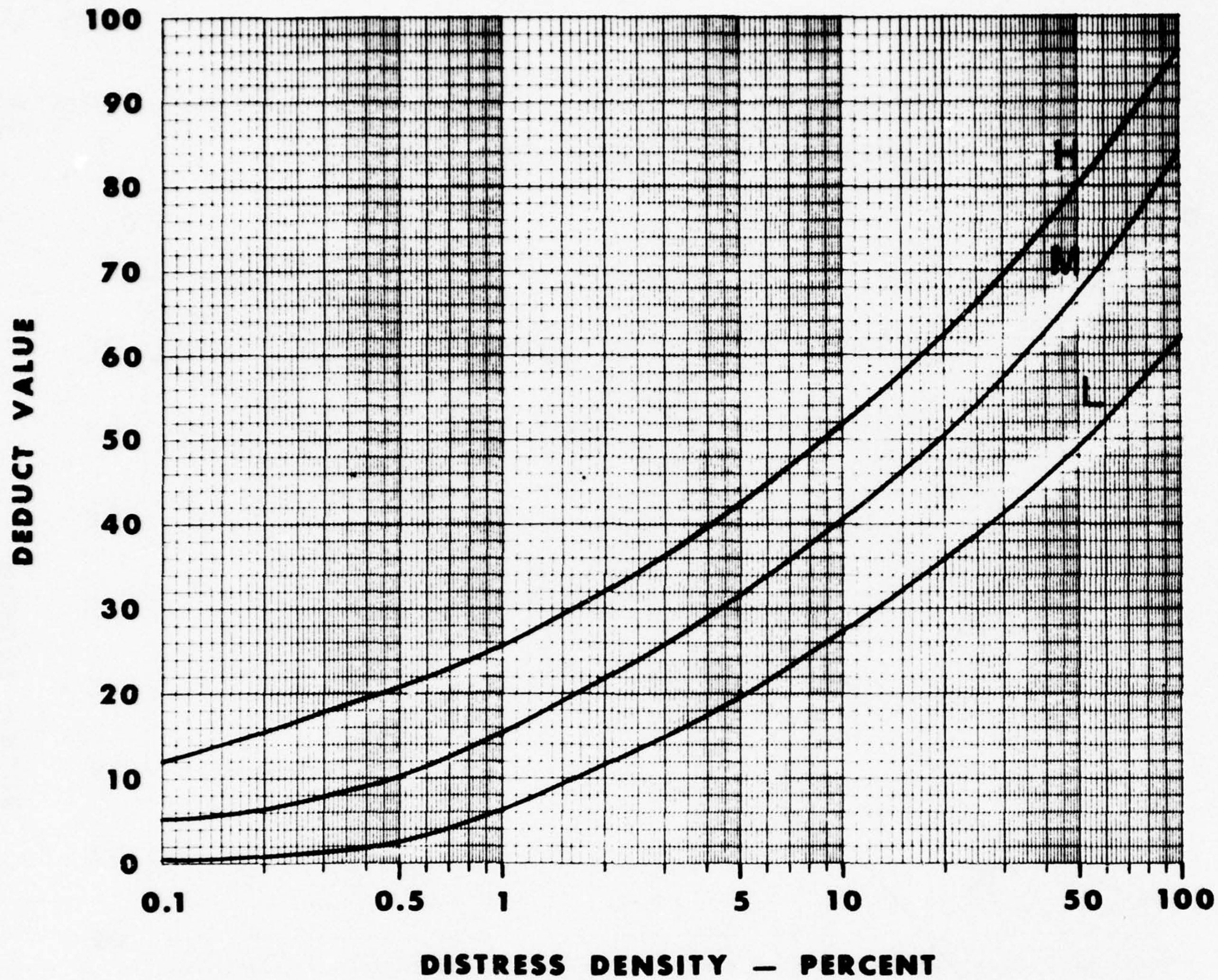
3. Block cracking.

Figure A-9. Asphalt- or Tar-Surfaced Pavement Deduct Values (continued).



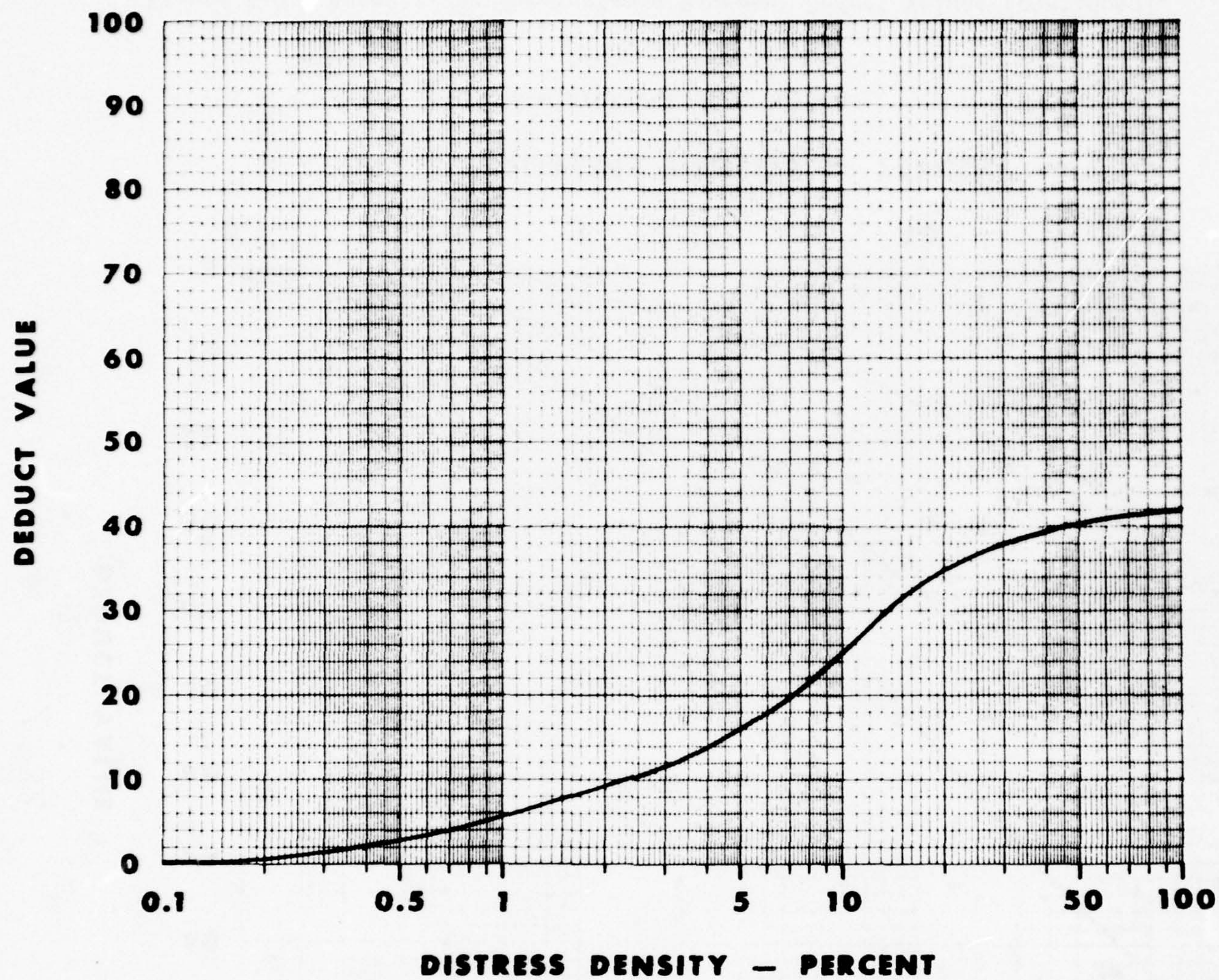
4. Corrugation.

Figure A-9. Asphalt- or Tar-Surfaced Pavement Deduct Values (continued).



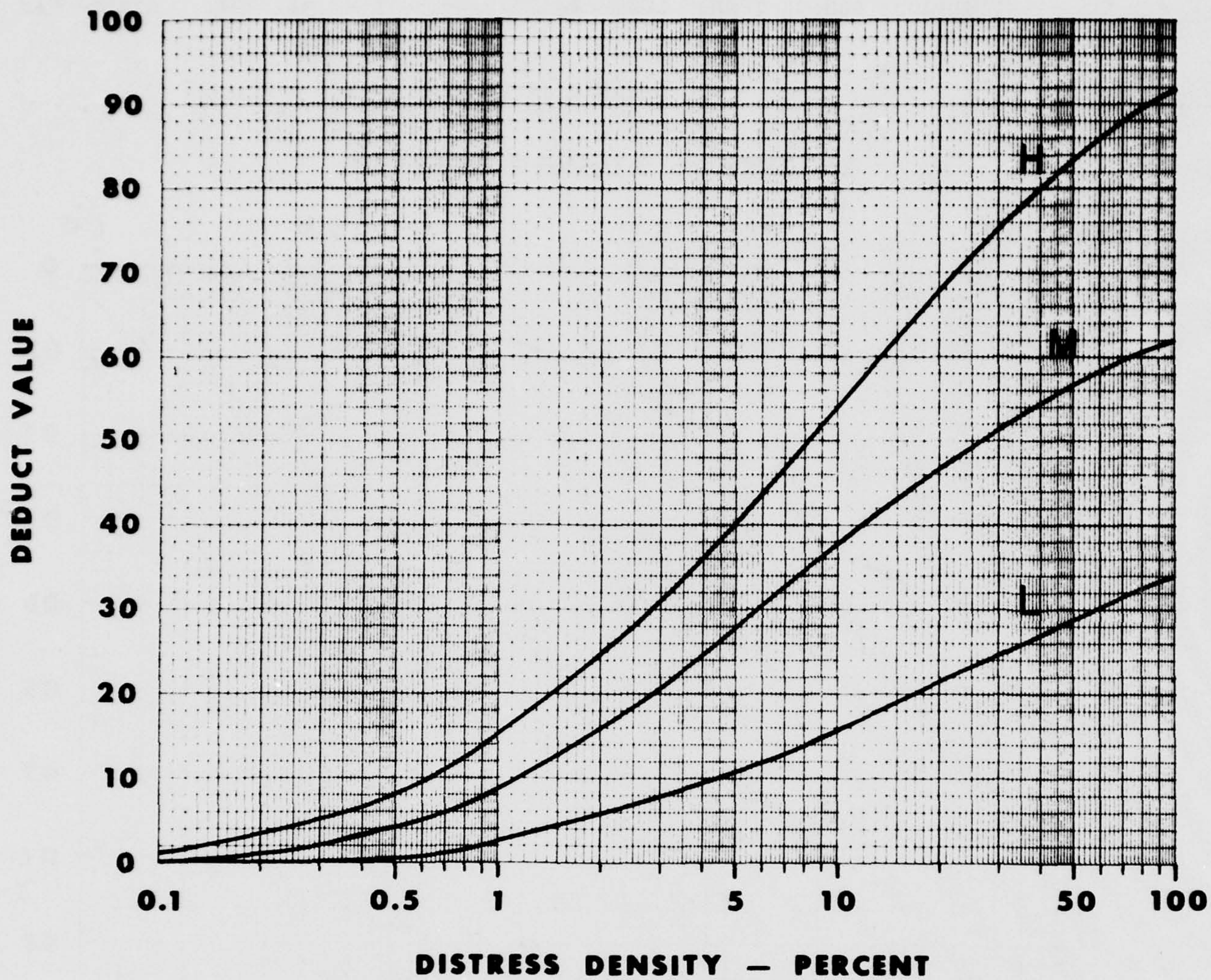
5. Depression.

Figure A-9. Asphalt- or Tar-Surfaced Pavement Deduct Values (continued).



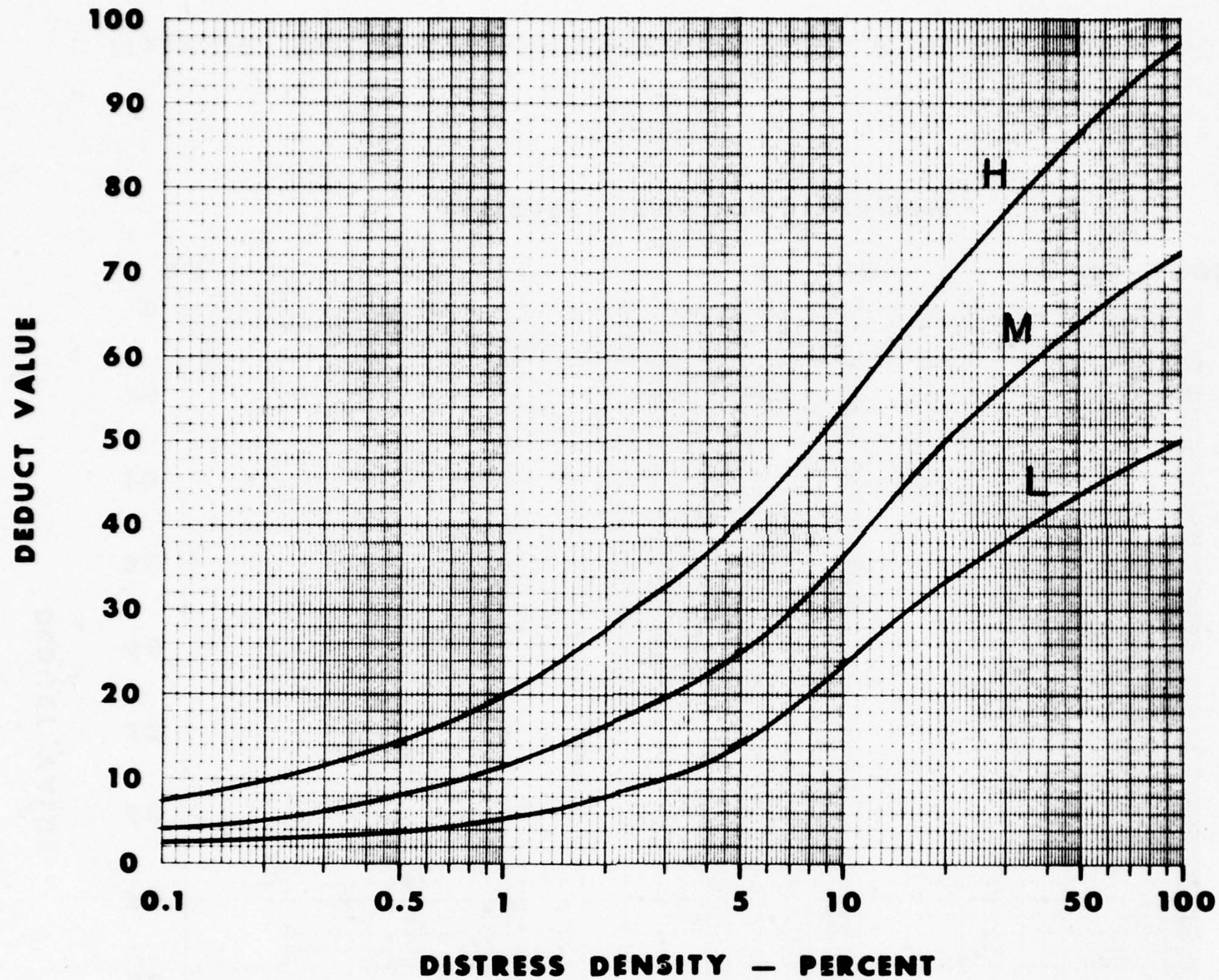
6. Jet blast erosion.

Figure A-9. Asphalt- or Tar-Surfaced Pavement Deduct Values (continued).



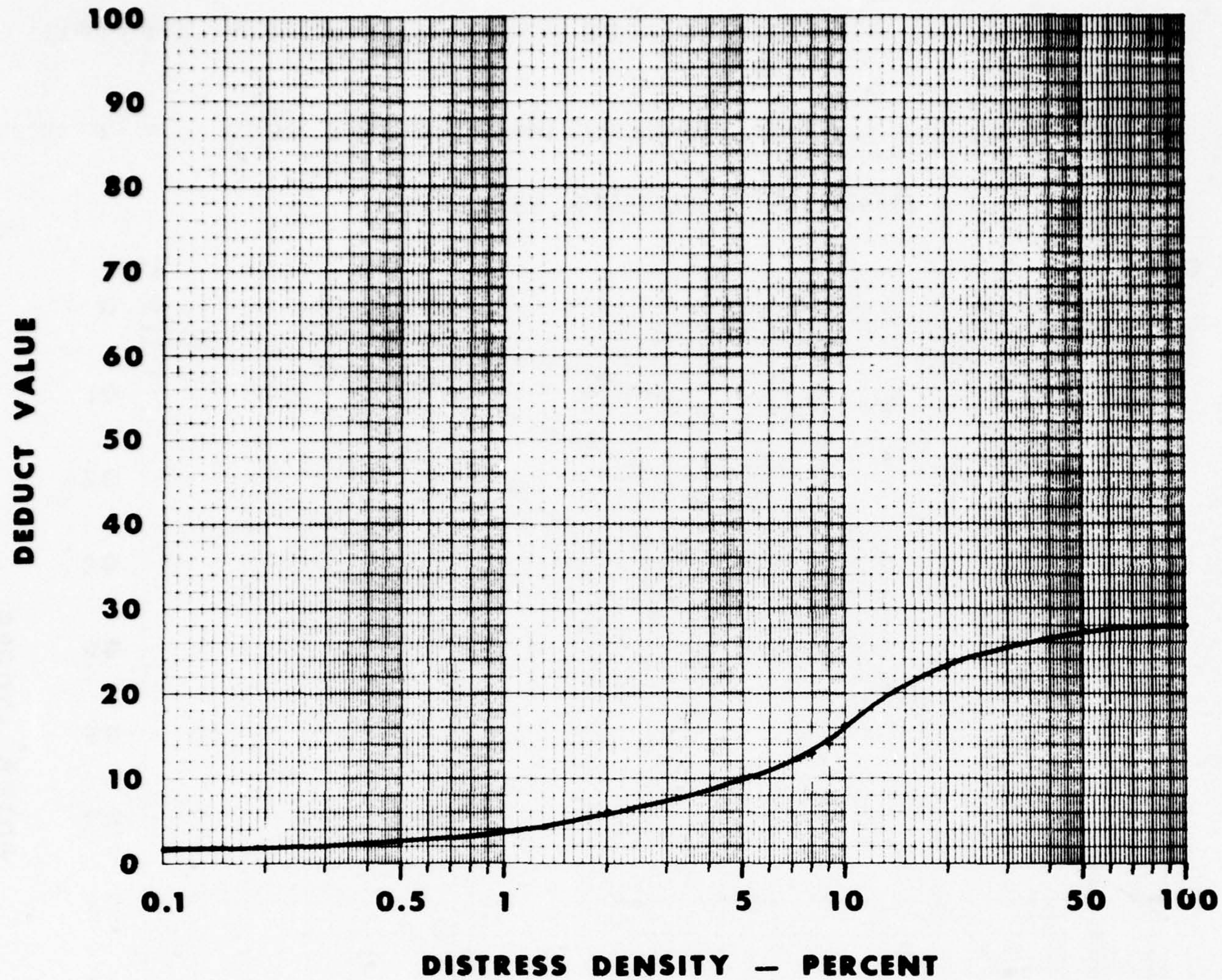
7. Joint reflection cracking.

Figure A-9. Asphalt- or Tar-Surfaced Pavement Deduct Values (continued).



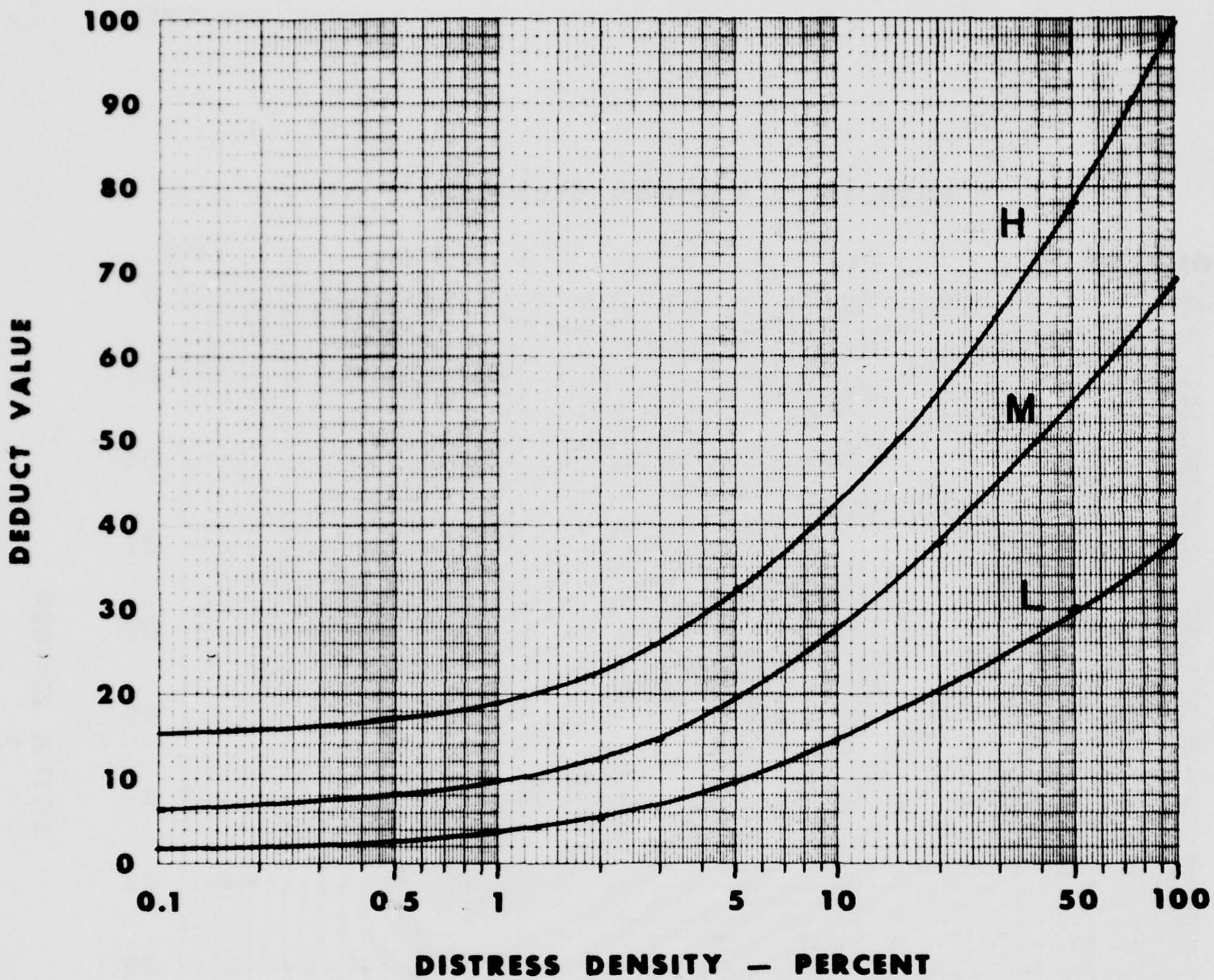
8. Longitudinal and transverse cracking.

Figure A-9. Asphalt- or Tar-Surfaced Pavement Deduct Values (continued).



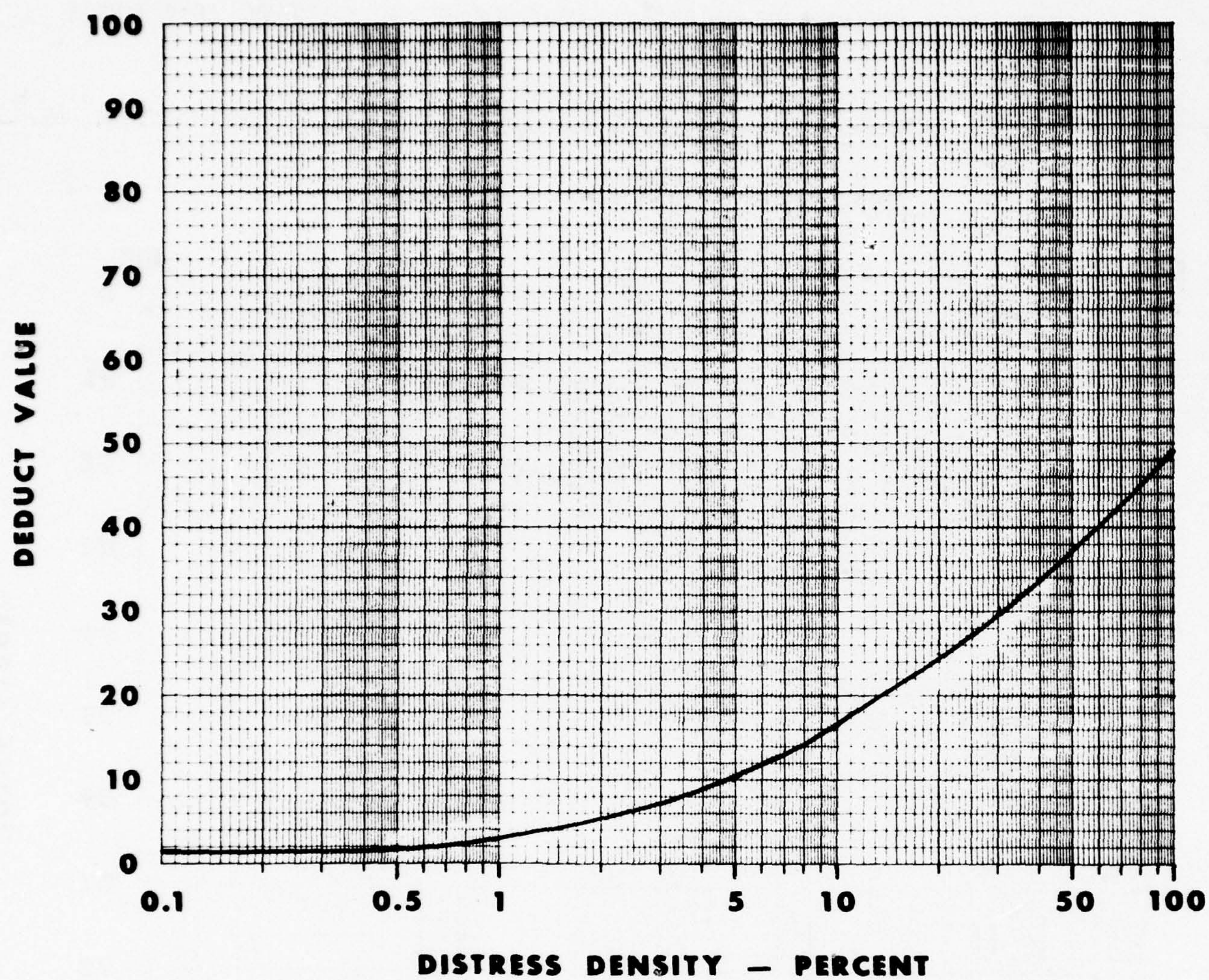
9. Oil spillage.

Figure A-9. Asphalt- or Tar-Surfaced Pavement Deduct Values (continued).



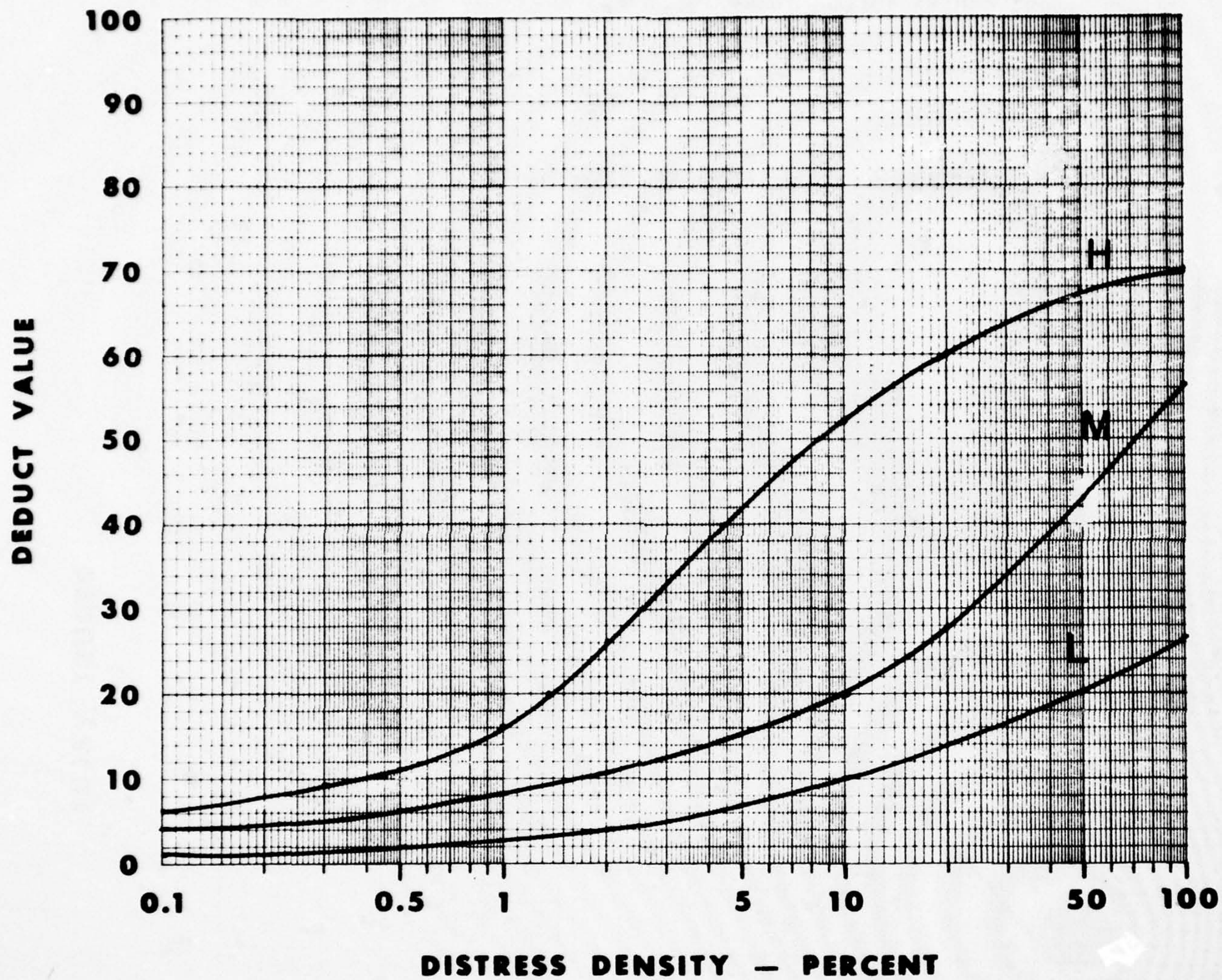
10. Patching and utility cut.

Figure A-9. Asphalt- or Tar-Surfaced Pavement Deduct Values (continued).



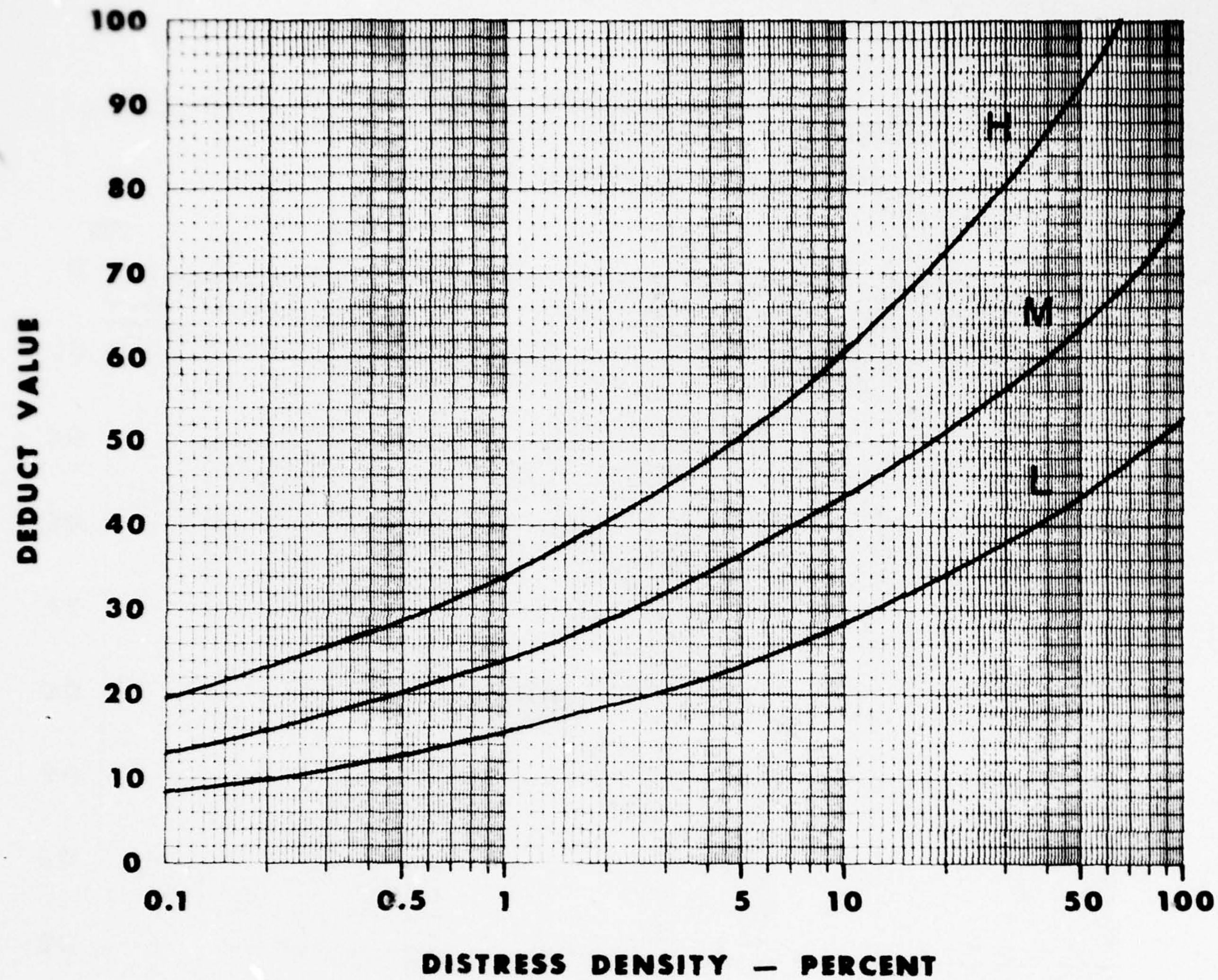
11. Polished aggregate.

Figure A-9. Asphalt- or Tar-Surfaced Pavement Deduct Values (continued).



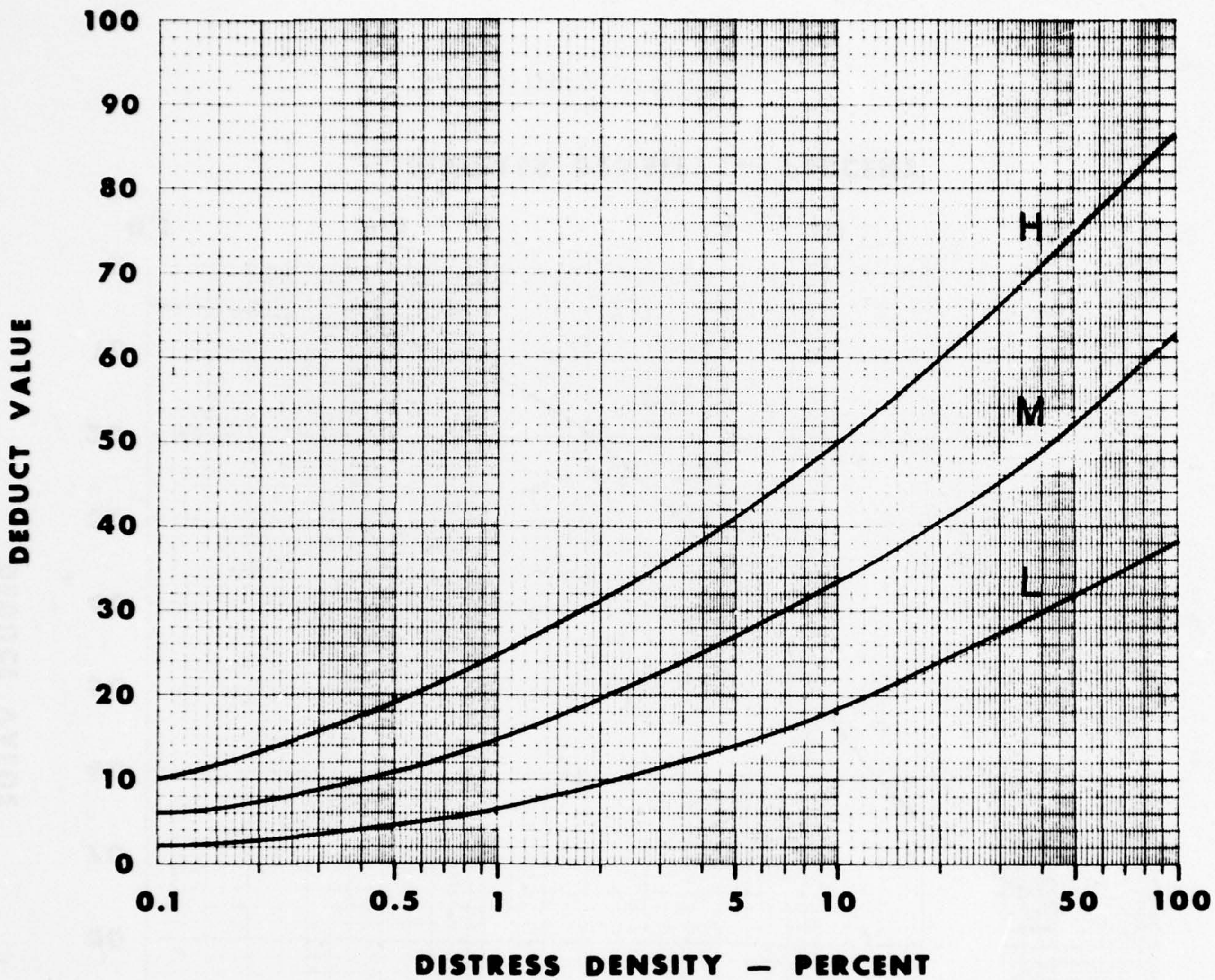
12. Raveling/weathering.

Figure A-9. Asphalt- or Tar-Surfaced Pavement Deduct Values (continued).



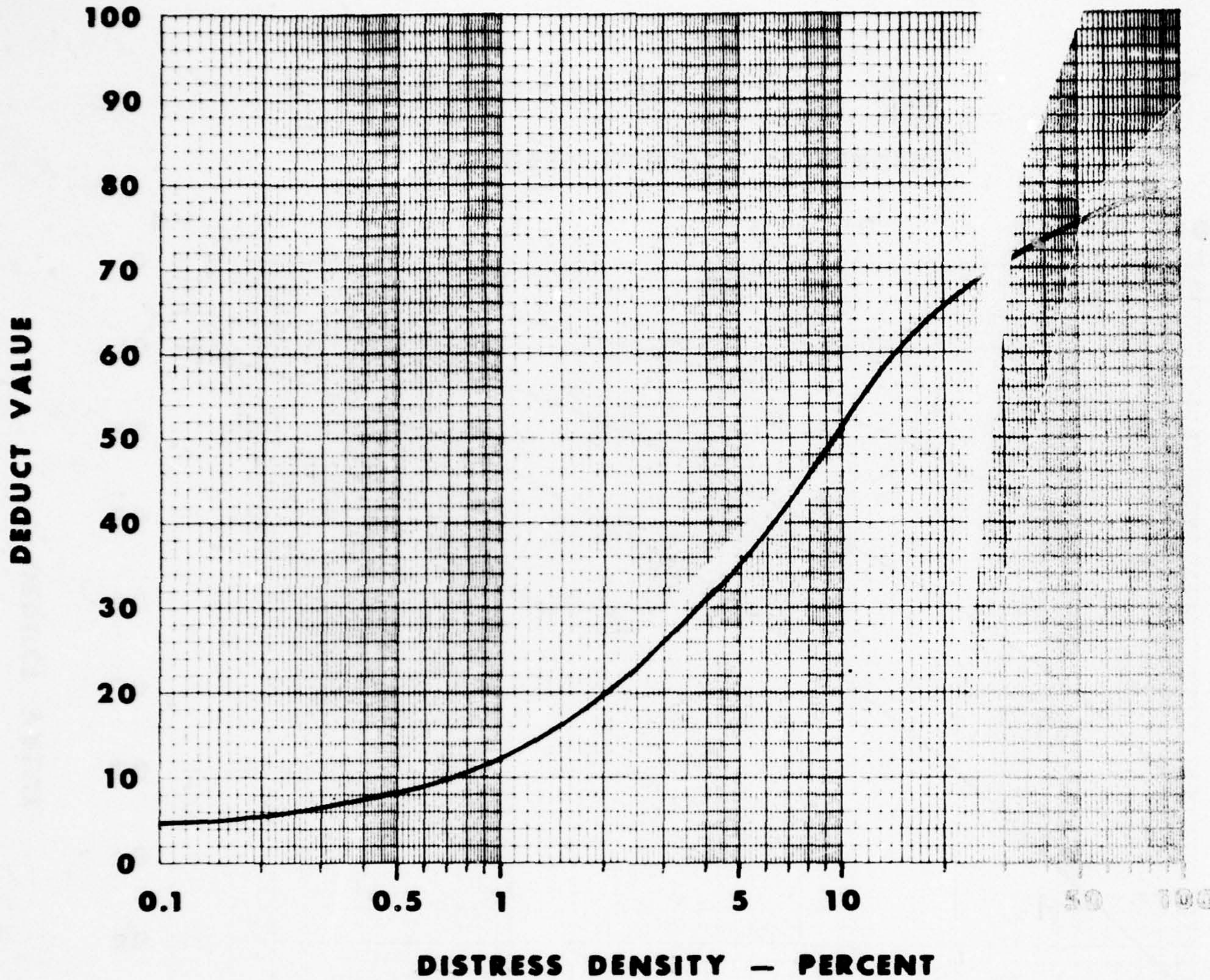
13. Rutting.

Figure A-9. Asphalt- or Tar-Surfaced Pavement Deduct Values (continued).



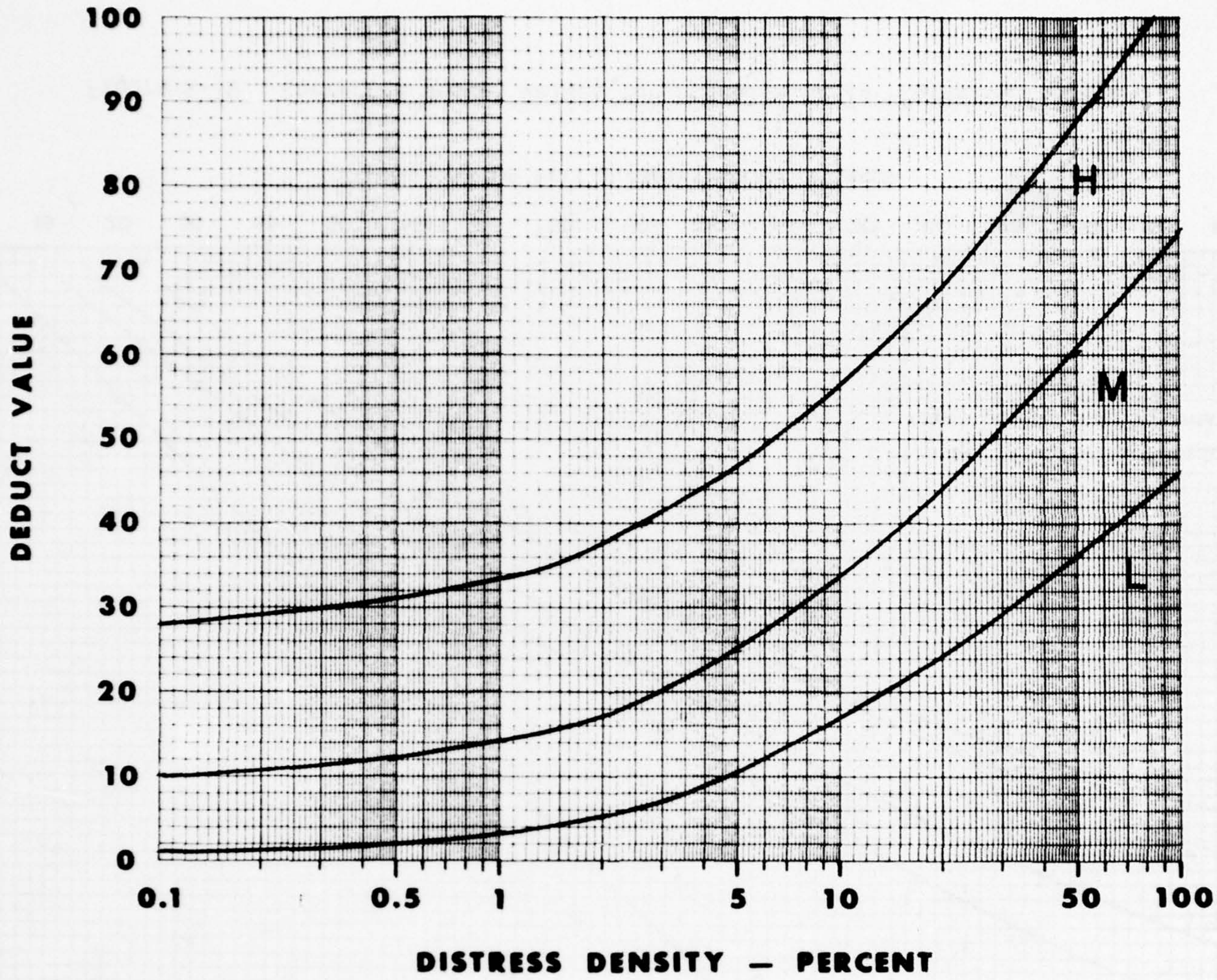
14. Shoving of flexible pavement by PCC slabs.

Figure A-9. Asphalt- or Tar-Surfaced Pavement Deduct Values (continued).



15. Slippage cracking.

Figure A-9. Asphalt- or Tar-Surfaced Pavement Deduct Values (continued).



16. Swell.

Figure A-9. Asphalt- or Tar-Surfaced Pavement Deduct Values (concluded).

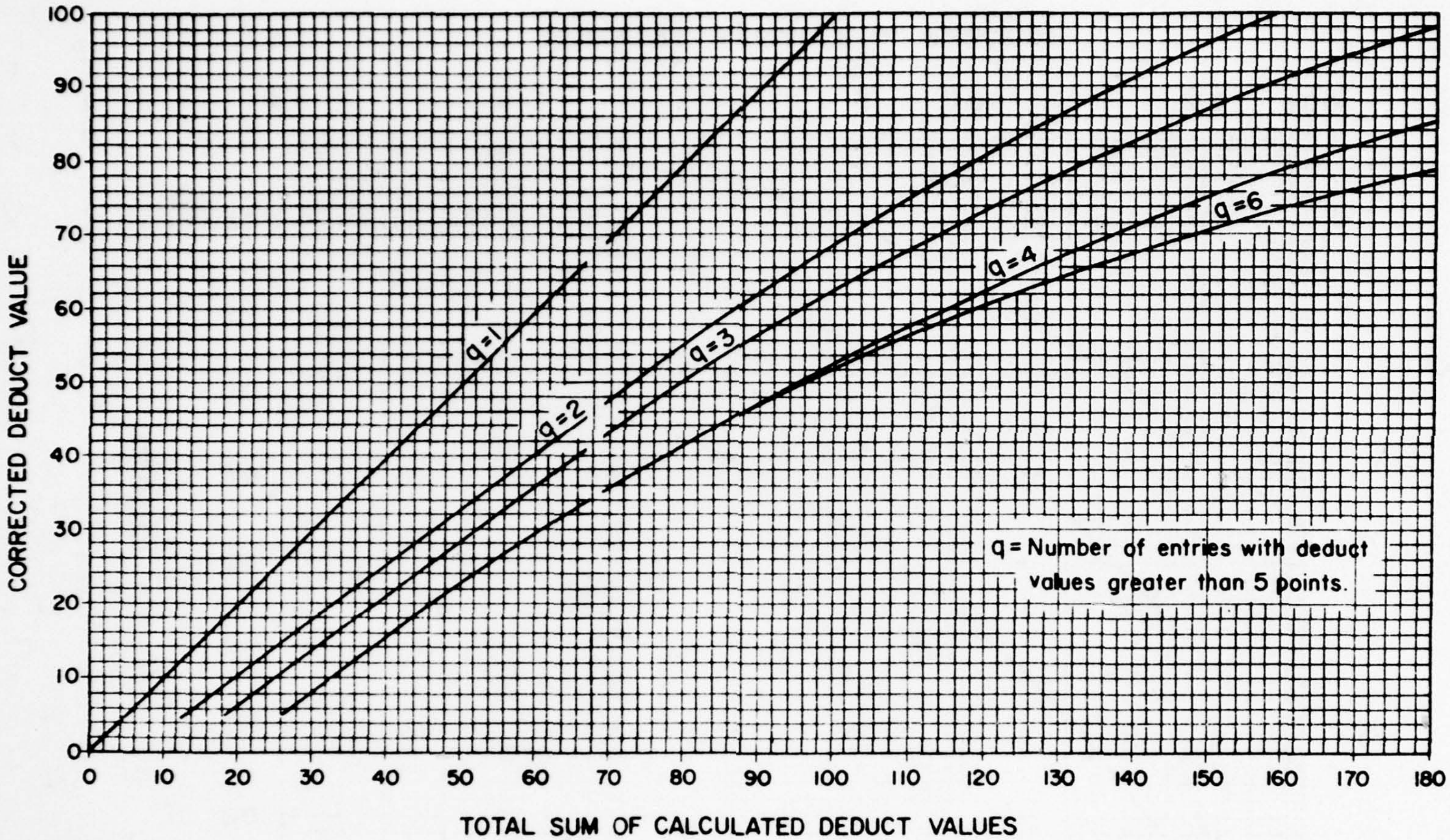


Figure A-10. Corrected Deduct Values for Asphalt- or Tar-Surfaced Pavements.

Pavement Feature: Taxiway 5

Total No. of Units: 25

Date of Survey: 7/13/76

Unit No.	Unit Area ft^2	PCI	Unit No.	Unit Area ft^2	PCI
1	5000	42	16	5000	35
2	5000	33	17	5000	22
3	5000	53	18	5000	30
4	5000	39	19	5000	39
5	5000	23	20	5000	35
6	5000	25	21	5000	32
7	5000	36	22	5000	41
8	5000	38	23	5000	49
9	5000	35	24	5000	30
10	5000	25	25	5000	22
11	5000	32			
12	5000	45			
13	5000	40			
14	5000	55			
15	5000	46			

Average PCI for feature: 36

Condition rating: Poor

Figure A-11. Feature Summary - Asphalt- or Tar-Surfaced Pavements.

6. Condition Survey by Sampling. Inspection of an entire feature may require considerable effort, especially if the feature is very large. This is particularly true for asphalt- or tar-surfaced pavements containing significant distress. Because of the time and effort involved, frequent surveys of the entire feature may be beyond available manpower, funds, and time; for example, closing a heavily used runway for any extended time period is difficult. A sampling plan has therefore been developed so that an adequate estimate of the PCI can be determined by inspecting only a portion of the sample units in a feature. Use of the statistical sampling plan described here will considerably reduce the time required to inspect a feature without significant loss of accuracy. Inspection of the entire feature may be desired or even necessary, however, if exact quantities of distress must be known for contractual maintenance work.

a. Number of Sample Units to Be Inspected. The number of sample units that must be surveyed to obtain an adequate estimate of the PCI of the feature depends on:

(1) How large an error can be tolerated in the estimate of the mean feature PCI (denoted by e).

(2) The desired probability that the PCI estimate will be within this limit of error (usually set fairly high, such as 95 percent).

(3) The estimate of the variation of the PCI (or standard deviation) from one sample unit to another within the feature (denoted by σ).

(4) The total number of sample units in the feature (denoted by N). For 95 percent confidence that the error in estimating the feature PCI is no greater than $\pm e$, the minimum number of sample units to be inspected, n, is calculated from the following equation.

$$n = \frac{N\sigma^2}{\left(\frac{e^2}{4}\right)(N-1) + \sigma^2} \qquad \text{[Equation A-1]}$$

For example, an asphalt-surfaced taxiway feature 50 feet wide and 2500 feet long must be inspected and the mean PCI determined. Convenient sample units of 50 x 100 feet are selected; 25 units result. Determining the true PCI of the feature within ± 5 points, with a confidence level of 95 percent, is desired. A standard deviation of 10 points is selected based on data obtained from many asphalt features. The parameters are therefore:

$N = 25$

$e = 5$ points

$\sigma = 10$ points

$$n = \frac{25\,(10^2)}{\left(\frac{5}{4}\right)^2 (25-1) + (10)^2} = 10$$

Therefore, a minimum of 10 sample units must be selected at random and inspected; the PCI of each unit, and the mean PCI of the feature are then computed based on the inspection data.

Plots which permit the number of required samples to be readily obtained were developed using Equation A-1. These graphs, shown in Figures A-12 and A-13, can be used to select the minimum number of sample units that must be inspected to provide a reasonable estimate of the true PCI of the feature. This estimate will be within ± 5 points approximately 95 percent of the time.

b. Selection of Sample Units to Be Inspected. Sample units must be selected randomly to assure an unbiased estimate of the pavement feature's PCI. If the total number of sample units in a feature exceeds 10, stratifying the feature is recommended. This involves dividing the feature into a number of parts called strata. An equal number of sample units are randomly selected from each strata, and the sample mean is computed by averaging the PCI of all surveyed sample units.

The following example illustrates the procedure of stratified random sampling. The feature to be inspected (Figure A-7) contains 25 sample units. The required minimum number of sample units is determined to be 10. The sample units are numbered from 1 to 25 beginning at one end. Strata can be selected in several ways, such as dividing the feature into five strata:

Strata 1	Sample units	1 through 5
Strata 2	Sample units	6 through 10
Strata 3	Sample units	11 through 15
Strata 4	Sample units	16 through 20
Strata 5	Sample units	21 through 25

Two sample units are selected at random from each strata using a random number table such as Table A-1. For the example, the units could be selected by starting at columns 05 and 06, and row 10, and proceeding down the page selecting two numbers from 1 to 5 (03 from row 16 and 01 from row 25), then 6 to 10, etc. Since the required sections are not obtained when the bottom of the column has been reached, the additional units can be obtained by proceed.ng upward from row 49 in columns 20 and 21. The sample units selected for the example using this procedure are:

Strata	Sample Units
Strata 1 (1-5)	01, 03
Strata 2 (6-10)	09, 10
Strata 3 (11-15)	12, 13

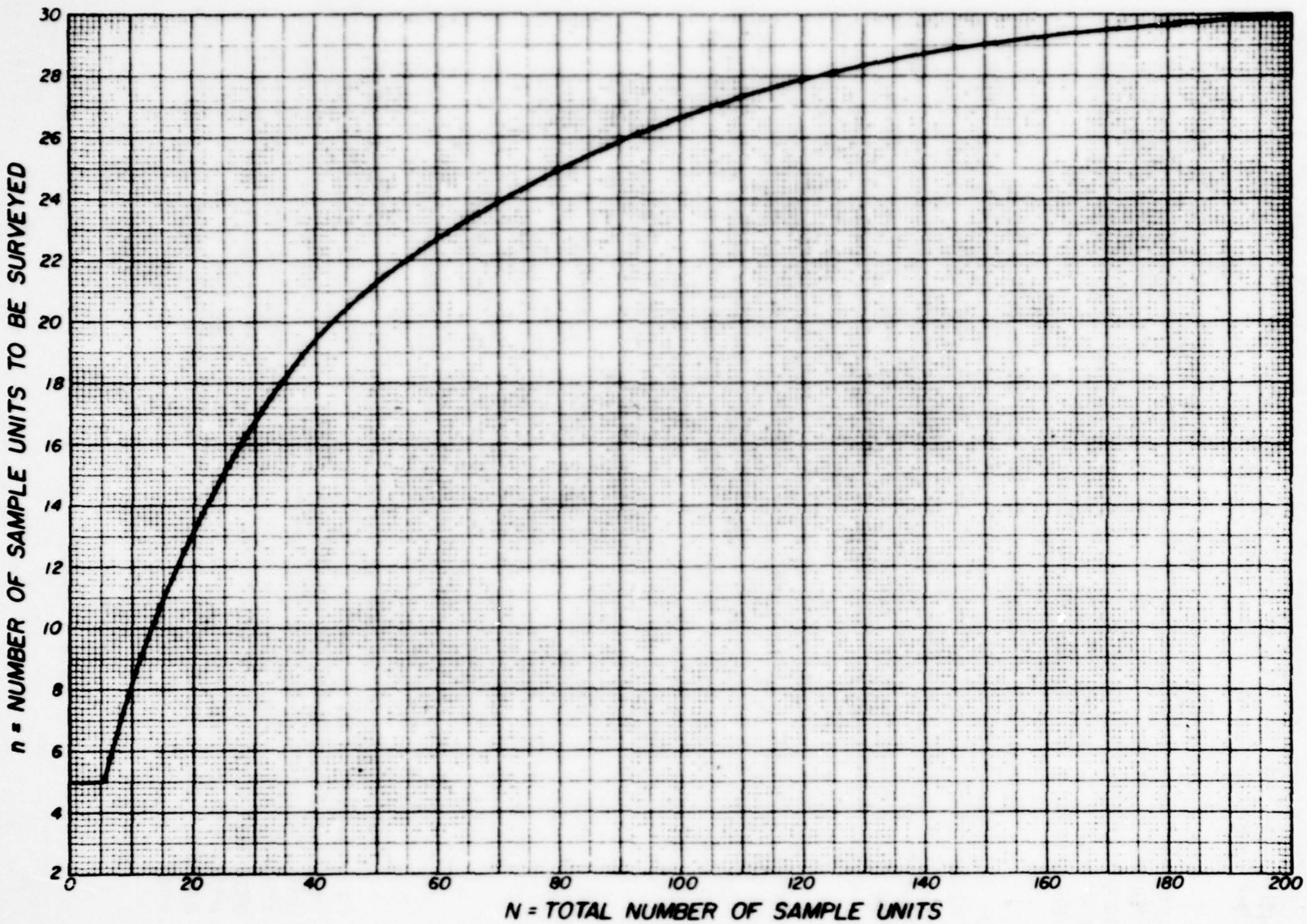


Figure A-12. Minimum Number of Sample Units Required for Jointed Concrete Pavement Features.

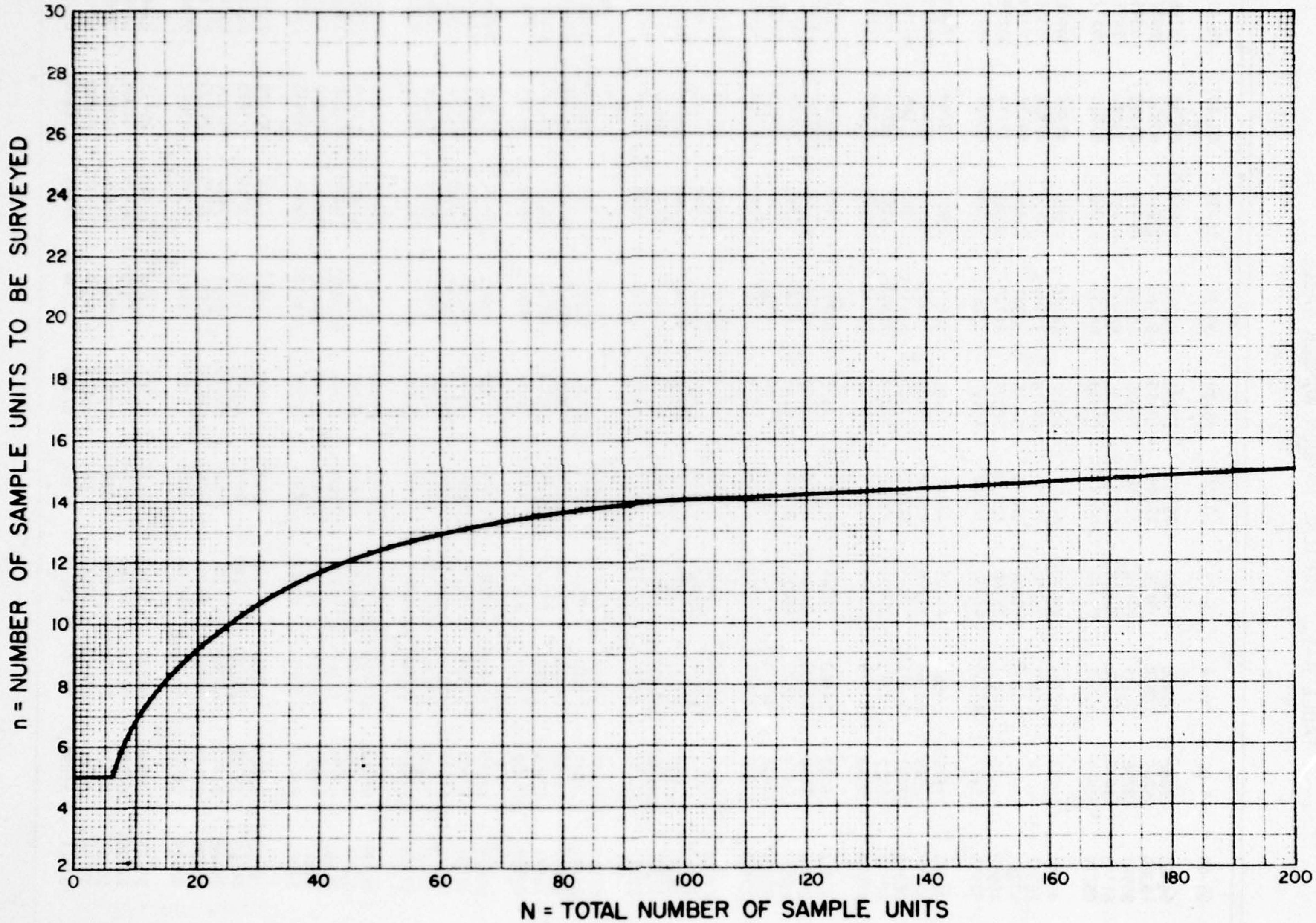


Figure A-13. Minimum Number of Sample Units Required for Asphalt- or Tar-Surfaced Pavement Features.

TABLE A-1. TYPICAL RANDOM NUMBER TABLE

	00-04	05-09	10-14	15-19	20-24	25-29	30-34	35-39	40-44	45-49
00	54463	22662	65905	70639	79365	67382	29085	69831	47058	08186
01	15389	85205	18850	39226	42249	90669	96325	23248	60933	26927
02	85941	40756	82414	02015	13858	78030	16269	65978	01385	15345
03	61149	69440	11286	88218	58925	03638	52862	62733	33451	77455
04	05219	81619	10651	67079	92511	59888	84502	72095	83463	75577
05	41417	98326	87719	92294	46614	50948	64886	20002	97365	30976
06	28357	94070	20652	35774	16249	75019	21145	05217	47286	76305
07	17783	00015	10806	83091	91530	36466	39981	62481	49177	75779
08	40950	84820	29881	85966	62800	70326	84740	62660	77379	90279
09	82995	64157	66164	41180	10089	41757	78258	96488	88629	37231
10	96754	17676	55659	44105	47361	34833	86679	23930	53249	27083
11	34357	88040	53364	71726	45690	66334	60332	22554	90600	71113
12	06318	37403	49927	57715	50423	67372	63116	48888	21505	80182
13	62111	52820	07243	79931	89292	84767	85693	73947	22278	11551
14	47534	09243	67879	00544	23410	12740	02540	54440	32949	13491
15	98614	75993	84460	62846	59844	14922	48730	73443	48167	34770
16	24867	03648	44898	09351	98795	18644	39765	71058	90368	44104
17	96887	12479	80621	66223	86085	78285	02432	53342	42846	94771
18	90801	21472	42815	77408	37390	76766	52615	32141	30268	18106
19	55165	77312	83666	36028	28420	70219	81369	41943	47366	41067
20	75884	12952	84318	95108	72305	64620	91381	89872	45375	35436
21	16777	37116	58550	42958	21460	43910	01175	87894	81378	10620
22	46230	43877	80207	88877	89380	32992	91380	03164	98656	59337
23	42902	66892	46134	01432	94710	23474	20423	60137	60609	13119
24	81007	00333	39693	28039	10154	95425	39220	19774	31782	49037
25	68089	01122	51111	72373	06902	74373	96199	97017	41273	21546
26	20411	67081	89950	16944	93054	87687	96693	87236	77054	33848
27	58212	13160	06468	15718	82627	76999	05999	58680	96739	63700
28	70577	42866	24969	61210	76046	67699	42054	12696	93758	03283
29	94522	74358	71659	62038	79643	79169	44741	05437	39038	13163
30	42626	86819	85651	88678	17401	03252	99547	32404	17918	62880
31	16051	33763	57194	16752	54450	19031	58580	47629	54132	60631
32	08244	27647	33851	44705	94211	46716	11738	55784	95374	72655
33	59497	04392	09419	89964	51211	04894	72882	17805	21896	83864
34	97155	13428	40293	09985	58434	01412	69124	82171	59058	82859
35	98409	66162	95763	47420	20792	61527	20441	39435	11859	41567
36	45476	84882	65109	96597	25930	66790	65706	61203	53634	22557
37	89300	69700	50741	30329	11658	23166	05400	66669	48708	03887
38	50051	95137	91631	66315	91428	12275	24816	68091	71710	33258
39	31753	85178	31310	89642	98364	02306	24617	09609	83942	23716
40	79152	53829	77250	20190	56535	18760	69942	77448	33278	48805
41	44560	38750	83635	56540	64900	42912	13953	79149	18710	68618
42	68328	83378	63369	71381	39564	05615	42451	64559	97501	65747
43	46939	38689	58625	08342	30459	85863	20781	09284	26333	91777
44	83544	86141	15707	96256	23068	13782	08467	89469	93842	55349
45	91621	00881	04900	54224	46177	55309	17852	27491	89415	23466
46	91896	67126	04151	03795	59077	11848	12630	98375	52068	60142
47	55751	62515	21108	80830	02263	29303	37204	96926	30506	09808
48	85156	87689	95493	88842	00664	55017	55539	17771	69448	87530
49	07521	56898	12236	60277	39102	62315	12239	07105	11844	01117

Strata 4 (16-20)	16, 17
Strata 5 (21-25)	21, 23

Each of these sample units must be inspected and its PCI determined. The mean PCI of the taxiway feature is then estimated as the mean of the 10 sample units. Using the data in Figure A-11, the PCI of the feature determined using the sample option is as shown in Figure A-14. PCI of the 10 sample units is 38, which is close to the true mean of 36, as given in Figure A-11.

One of the major objections to "random sampling" that engineers sometimes express is the problem of not including a very "poor" or "excellent" sample unit(s) which may exist in the feature. However, one or more additional samples may be selected by the engineer if desired; the following equation must then be used to compute the mean PCI:

$$PCI_f = \frac{(N - C)}{N} \overline{PCI_1} + \frac{C}{N} \overline{PCI_2} \qquad \text{[Equation A-2]}$$

where PCI_f = overall PCI of feature

N = total number of sample units in the feature or subfeature

C = number of additional sample units

$\overline{PCI_1}$ = arithmetic mean of PCI for random units

$\overline{PCI_2}$ = arithmetic mean of PCI for the additional sample units.

For example, if the mean PCI of the 10 sample units previously discussed was 38, and one additional section inspected because it had serious distress had a PCI of 10, the final PCI_f of the feature would be computed as:

$$PCI_f = \frac{(25-1)}{25} (38) + \frac{1}{25} (10) = 37$$

7. Airfield Pavement Condition Survey Reports. The format for reporting the findings of the major command-conducted airfield condition survey has been designed to preclude the necessity for extensive drafting and typing services at the command level. Presentation of the data in graphic or tabular form is desirable from the standpoint of simple interpretation. Rather than a complete summary of construction history and other repetitious data, the report will primarily reflect changes in the airfield pavement system which have occurred since the last report (either pavement evaluation or condition survey) was accomplished. The condition survey report format in Figure A-15 has been prepared for major command use to assure that the completed reports are standardized.

Pavement Feature: Taxiway 5B

Total No. of Units: 25

Date of Survey: 7/13/76

Unit No.	Unit Area ft^2	PCI	Unit No.	Unit Area ft^2	PCI
1	5000	42			
3	5000	53			
9	5000	35			
10	5000	25			
12	5000	45			
13	5000	40			
16	5000	35			
17	5000	22			
21	5000	32			
23	5000	49			

Average PCI for Feature: 38

Condition Rating: Poor

Figure A-14. Feature Summary--Asphalt- or Tar-Surfaced Pavements, Sampling Option.

TITLE PAGE AND COVER. The title page will indicate the major command responsible for the report, base on which the survey was performed, date of inspection, and date of the report.

1. Construction History. Reference the latest condition survey or pavement evaluation report and update construction history to depict airfield construction, maintenance, and repair projects accomplished since last survey or evaluation. Record the construction history changes in the same manner as presented in the last condition survey or evaluation report. Indicate whether pavement was built originally to light, medium, or heavy load design specifications.

2. Character and Composition of Aircraft Traffic and Load Repetitions. Provide a brief narrative paragraph which reflects past and present mission aircraft, by type and estimated frequency of operations.

3. Plans and Cross-Sections of Major Airfield Components:

a. Airfield Layout Plan. The airfield layout plan is an integral part of each report. It should be coded to depict airfield pavements required to support the mission; pavements not presently used, but maintained for possible mission support; and pavements not required and not maintained. The drawing should be symbol-keyed and annotated to indicate cracks, spalls, pop-outs, and other pavement defects as well as separately identifying pavement features. It should also reflect new construction, major repairs areas, and major maintenance project accomplishment.

b. Cross-Section. Cross-sections (pavement structure sections) should be provided in the report only when the original sections have been modified by major reconstruction, maintenance, or repair.

4. Character and Condition of Pavement Surfaces. Only general statements as to the condition of the various pavement facilities are desired; detailed results, such as the summary of defects, are not to be included in this section of the report. Any areas showing distress as noted during the condition survey will be described as to type of distress and extent. No conclusvie statements should be made regarding the effect of the pavement conditions on aircraft operations. (This is to be incorporated into item 7, Narrative Summary.)

5. Summary of Physical Property Data. Using the same format contained in the referenced condition survey or pavement evaluation report, change the summary to reflect the modifications to pavement structures resulting from recent airfield projects. Use asterisks to annotate the changes.

6. Summary of Allowable Gross Loads. Compute the allowable gross loads for pavement features which have been altered from the last evaluation report by reconstruction or other major change in the pavement structure. The computation procedure is outlined in AFM 88-24, chapters 2 and 3, for flexible and rigid pavements, respectively. Use the tabuiar in

Figure A-15. Condition Survey Report Format.

AD-A048 884 CONSTRUCTION ENGINEERING RESEARCH LAB (ARMY) CHAMPAI--ETC F/G 1/5
DEVELOPMENT OF A PAVEMENT MAINTENANCE MANAGEMENT SYSTEM. VOLUME--ETC(U)
DEC 77 M Y SHAHIN, M I DARTER, S D KOHN MIPR-FQ8952-76-66005

UNCLASSIFIED CERL-TR-C-76-VOL-1 CEEDO-TR-77-44-VOL-1 NL

3 OF 3

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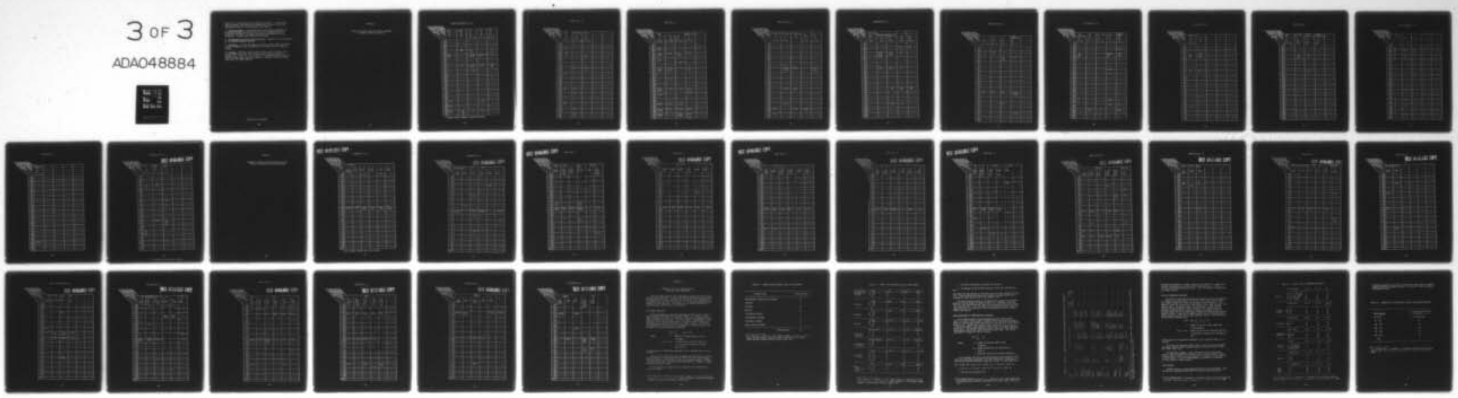

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DATE

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figure 4-1 of this regulation for displaying results. If there have been no changes, the summary of allowable gross loads will still be submitted as item 6 of the Condition Survey Report.

7. Narrative Summary. A paragraph which incorporates statements regarding operational condition of the airfield, recommendations for maintenance and repair, and major conclusions developed during the inspection. Problem areas should be highlighted.

8. Photographs Depicting Airfield Conditions. Optional at the discretion of the command pavements engineer.

9. Attachments. Attach the summary of defects and any other data which supports conclusions and recommendations developed from the Condition Survey.

10. Reports. The basic report size will be 8 x 10 1/2 inches. The maximum permissible size for a foldout sheet (drawing, gross load summary, etc.) is 15 1/2 x 10 1/2 inches. The completed report shall be securely bound; pages should be numbered in sequence; and each foldout sheet shall be folded properly.

Figure A-15 (concluded).

APPENDIX B

SUMMARY OF DISTRESS DATA FOR JOINTED CONCRETE PAVEMENTS FROM NINE AIRFIELDS

WRIGHT-PATTERSON AFB, OH

Distress Type	Distress Severity	R6B	R10D	T7C	T2A	14B
Feature		R6B	R10D	T7C	T2A	14B
Sample Unit		#1	#1	#1	#1	#1
No. of Slabs/Unit		40	20	54	30	20
Slab Size				25 x 25	25 x 25	25 x 25
1	L					
	M					
	H					
2	L					
	M					
	H					
3	L		90*	37		5
	M			9.6		
	H					
4	L	2.5		12.96	43.33	5
	M	2.5		11.11	10	
	H					
5	L					
	M					
	H					
6	L	10	35	74.07	93.33	60
	M			11.11		15
	H					
7	L			1.85		
	M					
	H					
8	L					
	M					15
	H					
9	L					
	M					
	H					
10	L					
	M					
	H					
11	L					
	M					
	H					
12	L					
	M					
	H					
13	L	2.5			3.33	
	M					
	H					
14	L	22.5				
	M					
	H					
15	L	17.5	15	3.7	6.67	
	M	7.5	15			
	H		5			

* VALUES INDICATE PERCENT SLABS WITH DISTRESS

GEORGE AFB, CA

Distress Type	Distress Severity	TW2	TW3,N,END	5C(Tu)		
Sample Unit		#1	#1	#11		
No. of Slabs/Unit		20	20	20		
Slab Size		12 x 15	12 1/2 x 25	25 x 25		
1	L					
	M					
	H					
2	L	20				
	M	5				
	H					
3	L	25				
	M	5				
	H	5		15		
4	L					
	M					
	H					
5	L	✓				
	M		✓			
	H			✓		
6	L		10	10		
	M			5		
	H					
7	L	10	5			
	M					
	H					
8	L					
	M					
	H					
9	L					
	M					
	H					
10	L	20	15			
	M					
	H					
11	L		5			
	M					
	H	5				
12	L					
	M					
	H	10				
13	L	25		5		
	M					
	H					
14	L		25			
	M					
	H					
15	L		10			
	M		10			
	H					

SCOTT AFB, IL

Feature / Sample Unit / No. of Slabs/Unit / Slab Size / Distress Type	Distress Severity	A9B			A3B(D to C)	
Sample Unit		#1	#2	#3	#1	
No. of Slabs/Unit		24	24	60	16	
Slab Size		12 1/2x30	12 1/2x30	12 1/2x30	12 1/2x21	
1	L					
	M					
	H					
2	L	4.17				
	M	8.33				
	H					
3	L	25	4.17	10	6.25	
	M	8.33		3.33		
	H					
4	L					
	M	4.17				
	H			1.67		
5	L					
	M				✓	
	H	✓	✓	✓		
6	L	8.33	4.17	5	25	
	M	8.33	12.5		25	
	H					
7	L					
	M					
	H					
8	L		4.17			
	M					
	H					
9	L					
	M					
	H					
10	L	29.17	4.17	25	12.5	
	M	4.17				
	H				6.25	
11	L	8.33				
	M					
	H					
12	L					
	M					
	H					
13	L	16.67	4.17	3.33		
	M					
	H					
14	L	8.33	37.5	3.33	18.75	
	M	4.17				
	H					
15	L	16.67		6.67	12.5	
	M	8.33		3.33		
	H				18.75	

HOMESTEAD AFB, FL

Distress Type	Distress Severity					
Feature		R/W 35/End	R/W Inter.	R/W Center		
Sample Unit		#2	#1	#13	#20	#31
No. of Slabs/Unit		16	21	21	21	21
Slab Size		25 x 25	25 x 25		25 x 25	25 x 25
1	L					
	M					
	H					
2	L					
	M					
	H					
3	L					
	M					
	H					
4	L					
	M					
	H					
5	L				√	√
	M	√	√			
	H					
6	L		14.29	14.29		4.76
	M		14.29			4.76
	H					
7	L					
	M					
	H					
8	L					
	M					
	H					
9	L					
	M					
	H					
10	L		9.52	9.52		
	M					
	H					
11	L					
	M					
	H					
12	L					
	M					
	H					
13	L		4.76			
	M					
	H					
14	L	6.25		4.76	4.76	
	M					
	H					
15	L	6.25				
	M					
	H					

HOMESTEAD AFB, FL

Feature		R/W Center			T/W	
Sample Unit		#40	Additional #1	Additional #2	#1	#2
No. of Slabs/Unit		21	21	21	20	20
Slab Size		25x25	25x25	25x25	25x25	25x25
Distress Type	**Distress Severity**					
1	L					
	M					
	H					
2	L				15	45
	M				5	
	H					
3	L		4.76	4.76	30	
	M		9.52	23.81		
	H		4.76			
4	L					
	M					
	H					
5	L	✓	✓			
	M					
	H					
6	L		9.52	19.05	10	
	M					
	H					
7	L					
	M					
	H					
8	L					
	M					
	H					
9	L					
	M					
	H					
10	L			100	100	100
	M					
	H					
11	L					
	M					
	H					
12	L					
	M					
	H					
13	L			4.76	5	
	M					
	H					
14	L					
	M					
	H					
15	L					
	M					
	H					

HOMESTEAD AFB, FL

Feature		T/W			Power Check Pad	
Sample Unit		#3	#4	#5	#1	
No. of Slabs/Unit		20	20	20	49	
Slab Size		25 x 25	25 x 25	25 x 25	15 x 15	
Distress Type	**Distress Severity**					
1	L					
	M					
	H					
2	L	5	10	10		
	M		5			
	H					
3	L	5		5	6.12	
	M			15		
	H			10		
4	L					
	M					
	H					
5	L					
	M					
	H				✓	
6	L		5			
	M					
	H					
7	L					
	M					
	H					
8	L					
	M					
	H					
9	L					
	M					
	H					
10	L	100	100	100	16.33	
	M				2.04	
	H					
11	L					
	M					
	H					
12	L			10		
	M					
	H					
13	L					
	M					
	H					
14	L				4.08	
	M					
	H					
15	L					
	M					
	H					

WILLIAMS AFB, AZ

Distress Type	Distress Severity					
	Feature	R/W 30L	R/W 30L	R/W 30R	T/W 6	South Apron
	Sample Unit	#1(M 9/1)	#2	#1	#1	#1
	No. of Slabs/Unit	30	30	20	30	30
	Slab Size	25 x 25	15 x 15	20 x 20	12 1/2x15	15x12 1/2
1	L					
	M					
	H					
2	L					3.33
	M					
	H					
3	L	20			36.67	40
	M	33			10	3.33
	H	3.33				
4	L					
	M					
	H					
5	L	✓			✓	
	M		✓			
	H					
6	L				23.33	
	M					
	H					
7	L				3.33	
	M					
	H					
8	L					
	M					
	H					
9	L					
	M					
	H					
10	L					
	M					
	H					
11	L					
	M					
	H					
12	L	10			3.33	
	M					
	H					
13	L				3.33	20
	M					
	H					
14	L		6.67	10		3.33
	M					
	H					
15	L			10		
	M					
	H					

WILLIAMS AFB, AZ

Distress Type	Distress Severity					
Feature		South Apron				
Sample Unit		#2	#3			
No of Slabs/Unit		20	16			
Slab Size		12 1/2 x15				
1	L					
	M					
	H					
2	L	15	37.5			
	M					
	H		6.25			
3	L	60	18.75			
	M	25	12.5			
	H					
4	L					
	M					
	H					
5	L					
	M					
	H					
6	L	30	50			
	M					
	H					
7	L					
	M					
	H					
8	L					
	M					
	H					
9	L					
	M					
	H					
10	L					
	M					
	H					
11	L		12.5			
	M					
	H					
12	L		12.5			
	M					
	H					
13	L	5				
	M					
	H					
14	L		12.5			
	M					
	H					
15	L					
	M					
	H					

CRAIG AFB, AL

Distress Type	Distress Severity	R/WAL	R/W 32RL	APRON 8"PCC 115"AC	APRON 10'ACC/SC	
Feature		R/WAL	R/W 32RL	APRON 8"PCC 115"AC	APRON 10'ACC/SC	
Sample Unit		#1	#1	#1	#1	
No. of Slabs/Unit		20	20	20	20	
Slab Size		12 1/2x15	17x25	17x25	18x25	
1	L					
	M					
	H					
2	L					
	M					
	H					
3	L		55	20	15	
	M		15	5		
	H		10			
4	L					
	M					
	H					
5	L	✓	✓	✓		
	M					
	H					
6	L			35		
	M			5		
	H					
7	L			5		
	M					
	H					
8	L					
	M					
	H					
9	L					
	M					
	H					
10	L	5				
	M					
	H					
11	L					
	M					
	H					
12	L					
	M					
	H					
13	L			5		
	M					
	H					
14	L					
	M					
	H					
15	L					
	M					
	H					

FORT WAINWRIGHT, AR

Distress Type	Distress Severity					
Feature		RUNWAY				
Sample Unit		#1	#2	#3		
No. of Slabs/Unit						
Slab Size						
1	L					
	M					
	H					
2	L	25	20	5		
	M	15	15	10		
	H	5				
3	L	20	5	5		
	M		15			
	H	5	5			
4	L					
	M					
	H					
5	L			✓		
	M	✓				
	H					
6	L	5				
	M					
	H					
7	L	10		35		
	M					
	H					
8	L					
	M					
	H					
9	L					
	M					
	H					
10	L		20			
	M					
	H					
11	L					
	M					
	H					
12	L	10	25	5		
	M	5				
	H					
13	L	35	25	45		
	M					
	H					
14	L			5		
	M	5				
	H		5			
15	L		5			
	M	5				
	H					

EIELSON AFB, AK

Distress Type	Distress Severity					
Feature		Refueling Pad				
Sample Unit		#1				
No. of Slabs/Unit		18				
Slab Size		25 x 25				
1	L					
	M					
	H					
2	L					
	M					
	H					
3	L					
	M					
	H					
4	L					
	M					
	H					
5	L					
	M					
	H	✓				
6	L					
	M					
	H					
7	L					
	M					
	H					
8	L					
	M					
	H					
9	L					
	M					
	H					
10	L					
	M					
	H					
11	L					
	M					
	H					
12	L					
	M					
	H					
13	L					
	M					
	H					
14	L	22.22				
	M					
	H					
15	L					
	M					
	H					

ELMENDORF AFB, AK

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Distress Type	Distress Severity	T/W #8	West Apron	East Apron		
Feature		T/W #8	West Apron	East Apron		
Sample Unit		#1	#1	#1		
No. of Slabs/Unit		20	21	20		
Slab Size		25 x 25	20 x 20	20 x 20		
1	L					
	M					
	H					
2	L					
	M					
	H					
3	L	5	9.52			
	M	15				
	H	5				
4	L					
	M					
	H					
5	L					
	M			✓		
	H					
6	L			20		
	M					
	H					
7	L			25		
	M					
	H					
8	L					
	M					
	H					
9	L					
	M					
	H					
10	L		4.76	20		
	M			45		
	H			20		
11	L					
	M					
	H					
12	L	35				
	M	30				
	H	10				
13	L					
	M					
	H					
14	L			20		
	M					
	H					
15	L					
	M					
	H					

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APPENDIX C

SUMMARY OF DISTRESS DATA FOR ASPHALT- OR TAR-SURFACED PAVEMENTS FROM EIGHT AIRFIELDS

BEST AVAILABLE COPY

ELMENDORF AFB, AK

Distress Type	Distress Severity						
Feature		E/W RW					
Sample Unit *		1	2	3	4	5	6
Sample Unit Area, FT2		3800	41-12	5434	4598	1560	4598
1	L	0.94*					
	M			0.13		0.33	
	H						
2	L						
	M						
	H						
3	L						
	M						
	H						
4	L						
	M						
	H						
5	L						
	M						
	H						
6	L						
	M						
	H						
7	L						
	M						
	H						
8	L	10.34	8.74	6.1	7.5	7.0	8.1
	M			0.7	0.1	0.15	0.33
	H						
9	L						
	M						
	H						
10	L						
	M						
	H						
11	L						
	M						
	H						
12	L						
	M						
	H						
13	L						
	M						
	H						
14	L						
	M						
	H						
15	L						
	M						
	H						
16	L						

* VALUE INDICATES PERCENT AREA WITH DISTRESS

ELMENDORF AFB, AK

Feature		E/W Runway	A-1	A-2	TW B		
Sample Unit #		7	1	1	1	2	3
Sample Unit Area, FT2		4560	4500	5300	3610	2964	3610
Distress Type	**Distress Severity**						
1	L				0.7		
	M						
	H						
2	L						
	M						
	H						
3	L					100	
	M						
	H						
4	L						
	M						
	H						
5	L			0.9			
	M						
	H						
6	L						
	M						
	H						
7	L		11.8				
	M						
	H						
8	L	9.1		10.2	22.9		21.66
	M	0.44			1.1		
	H						
9	L			0.8			
	M						
	H						
10	L						0.4
	M						
	H						
11	L						
	M						
	H						
12	L			0.3			
	M						
	H						
13	L						
	M						
	H						
14	L						
	M						
	H						
15	L						
	M						
	H						
16	L						

BEST AVAILABLE COPY

SCOTT AFB, IL

Feature		R3C	R4C		Tax F	TW 13B	
Sample Unit #		1	1	2	All	1	2
Sample Unit Area, FT2		5000	5000	5000	21,700	5250	5000
Distress Type	**Distress Severity**						
1	L		1.5	4.8			0.03
	M		1.5				0.72
	H						
2	L						
	M						
	H						
3	L						
	M						
	H						
4	L						
	M						
	H						
5	L						
	M						
	H						
6	L						
	M						
	H						
7	L	7.4			7.1		
	M	2.3			0.6		
	H						
8	L	6.6	5.6	6.5	0.3	.2	0.12
	M	3.4	1.2	1.7	0.05		
	H						
9	L						
	M						
	H						
10	L		1.7		5	.3	
	M				0.2		
	H						
11	L						
	M						
	H						
12	L						
	M						
	H						
13	L						0.12
	M						
	H						
14	L						
	M						
	H						
15	L						
	M						
	H						
16	L						

SCOTT AFB, IL

Distress Type	Distress Severity	TW 13 B					
Sample Unit #		3	4	5	6	7	8
Sample Unit Area, FT2		5000	5000	5000	5000	5000	5000
1	L				0.4		
	M						
	H						
2	L						
	M						
	H						
3	L						
	M						
	H						
4	L						
	M						
	H						
5	L					0.12	
	M						
	H						
6	L						
	M						
	H						
7	L						
	M						
	H						
8	L	1.3	0.5	0.9	0.1	0.6	0.6
	M						
	H						
9	L						
	M						
	H						
10	L						
	M						
	H						
11	L						
	M						
	H						
12	L	5.0					
	M						
	H						
13	L						
	M						
	H						
14	L						
	M						
	H						
15	L						
	M						
	H						
16	L						

BEST AVAILABLE COPY

SCOTT AFB, IL

Feature		TW 13 B					
Sample Unit #		9	10	11	12	13	14
Sample Unit Area, FT2		5000	5000	5000	5000	5000	5000
Distress Type	**Distress Severity**						
1	L	0.6		0.12	0.12		0.72
	M						
	H						
2	L						
	M						
	H						
3	L						
	M						
	H						
4	L						
	M						
	H						
5	L						
	M						
	H						
6	L						
	M						
	H						
7	L						
	M						
	H						
8	L	0.62	0.4	0.4	0.4	0.2	0.6
	M						
	H						
9	L						
	M						
	H						
10	L					2.7	
	M						
	H						
11	L						
	M						
	H						
12	L	5.0	3.0				
	M						
	H						
13	L						
	M						
	H						
14	L						
	M						
	H						
15	L						
	M						
	H						
16	L						

SCOTT AFB, IL

Feature		TW 13 B					
Sample Unit #		15	16	17	18	19	20
Sample Unit Area, FT2		5000	5000	5000	5000	5000	5000
Distress Type	Distress Severity						
1	L	0.21	0.24			0.72	1.4
	M						
	H						
2	L						
	M						
	H						
3	L						
	M						
	H						
4	L						
	M						
	H						
5	L						
	M						
	H						
6	L						
	M						
	H						
7	L						
	M						
	H						
8	L	0.12	0.42	0.76	.3	0.62	0.5
	M						
	H						
9	L						
	M						
	H						
10	L						
	M						
	H						
11	L						
	M						
	H						
12	L						
	M						
	H						
13	L						
	M						
	H						
14	L						
	M						
	H						
15	L						
	M						
	H						
16	L						

SCOTT AFB, IL

Feature		TW 13 B		TW (S)		A (S)	
Sample Unit #		21	22	1	2	3	
Sample Unit Area, FT2		5000	5000	4620	4620	5000	
Distress Type	**Distress Severity**						
1	L	2.2	0.72	3.6			
	M		0.18	15.7	45.2		
	H						
2	L						
	M						
	H						
3	L					80.0	
	M						
	H						
4	L						
	M						
	H						
5	L						
	M						
	H						
6	L						
	M						
	H						
7	L						
	M						
	H						
8	L	0.3	1.0	4.8	5.6		
	M		0.2	0.3	0.1		
	H						
9	L					4.3	
	M						
	H						
10	L	0.2					
	M						
	H						
11	L						
	M						
	H						
12	L		0.9				
	M						
	H						
13	L			0.65	18.2		
	M						
	H						
14	L						
	M						
	H						
15	L						
	M						
	H						
16	L						

HOMESTEAD AFB, FL

Distress Type	Distress Severity	PAR TW					OLD TW
Sample Unit #		7	14	33	46	ADD1	1
Sample Unit Area, FT2		5000	5000	5000	5000	5000	5000
1	L	11.88	14.0	0.72	2.18	6.4	12
	M						
	H						
2	L						
	M						
	H						
3	L				3.6		
	M						
	H						8.0
4	L						
	M						
	H						
5	L		0.2	1.2		0.5	0.5
	M					1.2	
	H						
6	L						
	M						
	H						
7	L						
	M						
	H						
8	L	0.7	2.6		.86	0.3	
	M						
	H						
9	L						
	M						
	H						
10	L						
	M		0.8				4.4
	H						
11	L						
	M						
	H						
12	L	0.8	40			100	
	M						
	H						
13	L	10.8	4.0	1.32	5.18	5.5	
	M						
	H						
14	L						
	M						
	H						
15	L						
	M						
	H						
16	L						

HOMESTEAD AFB, FL

Feature / Distress Type	Distress Severity	TK-6	TK-9	TWAY			
Sample Unit #							
Sample Unit Area, FT2		5310	5000	4500			
1	L	3.3					
	M						
	H						
2	L						
	M						
	H						
3	L	100		22			
	M		100				
	H						
4	L						
	M						
	H						
5	L						
	M						
	H						
6	L						
	M						
	H						
7	L						
	M						
	H						
8	L			3.3			
	M						
	H						
9	L						
	M						
	H						
10	L						
	M						
	H						
11	L						
	M						
	H						
12	L						
	M						
	H						
13	L						
	M						
	H						
14	L						
	M						
	H						
15	L						
	M						
	H						
16	L						

CRAIG AFB, AL

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Feature		R14L 6/4	R14L 6/2	TAXI 3B			AUX RW
Sample Unit #		1	1	1	2	3	1
Sample Unit Area, FT2		5625	5183	3750	3750	3750	4200
Distress Type	**Distress Severity**						
1	L						
	M						
	H						
2	L						
	M						
	H						
3	L						
	M						
	H						
4	L						
	M						
	H						
5	L						0.4
	M						
	H						
6	L						
	M						
	H						
7	L						
	M						
	H						
8	L	5.3	1.4	3.9	7.2	3.3	
	M						
	H						
9	L						
	M						
	H						
10	L						13.1
	M						1.0
	H						
11	L						
	M						
	H						
12	L	20.0	4.1		0.1		
	M						
	H						
13	L						
	M						
	H						
14	L						
	M						
	H						
15	L						
	M						
	H						
16	L						

CRAIG AFB, AL

BEST AVAILABLE COPY

Feature		AUX RW END	TW7				
Sample Unit #							
Sample Unit Area, FT2		4000	3750				
Distress Type	**Distress Severity**						
1	L						
	M						
	H						
2	L						
	M						
	H						
3	L		16.0				
	M						
	H						
4	L						
	M						
	H						
5	L	8.0					
	M						
	H						
6	L						
	M						
	H						
7	L						
	M						
	H						
8	L	2.5					
	M						
	H						
9	L						
	M						
	H						
10	L						
	M						
	H						
11	L						
	M						
	H						
12	L		4.8				
	M						
	H						
13	L						
	M						
	H						
14	L						
	M						
	H						
15	L						
	M						
	H						
16	L						

Distress Type	Distress Severity	R3C	T12B	T23B	T24B		
Sample Unit #		#1	#1	#1	#1		
Sample Unit Area, FT2		10,000	10,500	2640	2520		
1	L						
	M						
	H						
2	L						
	M						
	H						
3	L			22.2			
	M						
	H						
4	L						
	M						
	H						
5	L						
	M						
	H						
6	L	0.3					
	M						
	H						
7	L	7.9	5.5	12.9	19.5		
	M		5.5	6.0			
	H						
8	L		1.4	10.1	0.7		
	M						
	H						
9	L						
	M						
	H						
10	L						
	M						
	H						
11	L						
	M						
	H						
12	L			45.5			
	M						
	H						
13	L						
	M						
	H						
14	L						
	M						
	H						
15	L						
	M						
	H						
16	L						

WILLIAMS AFB, AZ

Distress Type	Distress Severity	TW4	R30 @END	30 M7/2	RW		TW6
Sample Unit #		#1	#1	#1	#1	#2	#1
Sample Unit Area, FT2		5000	7500	14,000	10,000	10,000	4500
1	L			0.03			
	M		2.7				
	H	0.4					
2	L						
	M						
	H						
3	L						
	M				80.0	80.0	
	H				20.0	20.0	
4	L						
	M						
	H						
5	L		0.7				
	M						
	H						
6	L						
	M						
	H						
7	L						17.8
	M						
	H						
8	L	3.7	6.5	2.6			1.6
	M	0.4	2.7				
	H						
9	L						
	M						
	H						
10	L						
	M						
	H						
11	L						
	M						
	H						
12	L			1.1			
	M						
	H						
13	L						
	M						
	H						
14	L						
	M						
	H						
15	L						
	M						
	H						
16	L						

GEORGE AFB, CA

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Distress Type	Distress Severity	TW6	TW5B				
Sample Unit #		#1	#2	#3	#4	#5	#6
Sample Unit Area, FT2		3700	3700	3700	3700	3700	3700
1	L	2.2	2.2	0.2	8.6	4.7	1.5
	M	1.1	3.6	1.4	2.0	24.4	20.3
	H						
2	L		4.3				
	M						
	H						
3	L	73.0	62.0	45.9	40.5	37.8	20.0
	M						
	H						
4	L		0.4				
	M						
	H						
5	L						
	M						
	H						
6	L						
	M						
	H						
7	L						
	M						
	H						
8	L	0.8	0.7	3.9	3.2	2.8	0.5
	M			0.4			
	H						
9	L						
	M						
	H						
10	L						52.0
	M						
	H						
11	L						
	M						
	H						
12	L						
	M						
	H						
13	L	1.1				4.3	
	M						
	H						
14	L						
	M						
	H						
15	L						
	M						
	H						
16	L						

GEORGE AFB, CA

Feature		TW5B					
Sample Unit #		#7	#8	#9	#10	#11	
Sample Unit Area, FT2		3700	3700	3700	3700	3700	
Distress Type	**Distress Severity**						
1	L	1.9	11.0	3.8	1.1	1.7	
	M	7.7	1.9	2.7	5.7	1.4	
	H						
2	L						
	M						
	H						
3	L	75.7	67.6	67.6	51.4	78.3	
	M						
	H						
4	L						
	M						
	H						
5	L						
	M						
	H						
6	L						
	M						
	H						
7	L						
	M						
	H						
8	L	3.7	1.9	4.2	2.0		
	M						
	H						
9	L						
	M						
	H						
10	L						
	M						
	H						
11	L						
	M						
	H						
12	L						
	M						
	H						
13	L	5.4		0.8		1.1	
	M					2.2	
	H				4.4		
14	L						
	M						
	H						
15	L						
	M						
	H						
16	L						

EIELSON AFB, AK

Distress Type	Distress Severity						
Feature		RUNWAY					
Sample Unit #		1	2	3	4	5	6
Sample Unit Area, FT2		4160	5280	4400	5000	5635	
1	L	0.75		0.82			
	M						
	H						
2	L						
	M						
	H						
3	L	100.00	90.0			100.00	100.00
	M		10.0				
	H						
4	L						
	M						
	H						
5	L						
	M						
	H						
6	L						
	M						
	H						
7	L						
	M						
	H						
8	L			8.4	13.5		
	M						
	H						
9	L						
	M						
	H						
10	L						
	M						
	H						
11	L						
	M						
	H						
12	L						
	M						
	H						
13	L			0.82			
	M						
	H						
14	L						
	M						
	H						
15	L						
	M						
	H						
16	L						

EIELSON AFB, AK

Feature		RUNWAY			TW6		
Sample Unit #		7	8	9	1	3	
Sample Unit Area, FT2		5000	2940	5000	3240	3240	
Distress Type	**Distress Severity**						
1	L	0.06			0.93	0.93	
	M				4.85		
	H				0.62		
2	L						
	M						
	H						
3	L	100.00		100.00			
	M						
	H						
4	L						
	M						
	H						
5	L						
	M						
	H						
6	L			75.0			
	M						
	H						
7	L						
	M						
	H						
8	L		22.2		5.6	12.1	
	M				0.4	0.9	
	H				0.6		
9	L						
	M						
	H						
10	L				1.2	0.08	
	M				0.37		
	H						
11	L						
	M						
	H						
12	L						
	M						
	H						
13	L						
	M						
	H						
14	L						
	M						
	H						
15	L						
	M						
	H						
16	L						

APPENDIX D

SUMMARY OF SELECTED HIGHWAY AGENCIES CONDITION INDEX PROCEDURES

Several highway agencies have developed procedures for determining a pavement condition index. Although the methods were developed for highway pavements, the general concepts are applicable to the development of a condition index for airfield pavements. This appendix summarizes the methods of three agencies: King County, WA, the Maine Department of Transportation, and the State of Washington.

KING COUNTY PROCEDURE

The King County, WA, procedure developed by Voss, et al.,[22] uses a credit system to determine the condition index. In a credit system, positive numerical values are credited to individual distresses at given levels of density and severity. A maximum credit is designated if the distress is not found on the pavement. If the distress is found at a high degree of severity and density, the credit is zero. All credits are accumulated, and their sum is the pavement's condition index. The procedure can be expressed by the equation:

$$PCI^* = \sum_{i=1}^{n} a(T_i, S, D)$$

where n = number of distress types in the procedure

$a(T_i, S, D)$ = credit of each distress type (T_i) as a function of severity (S) and density (D).

*Riding quality is determined separately, and a combined index is calculated.

Table D-1 shows the distresses and maximum credits used in the King County procedure. Summing the maximum credits for each distress type indicates that 60 is the maximum score for a pavement section. Table D-2 contains the credits assigned to the distresses as a function of their severity and density levels.

As an example, a pavement section containing the following distresses is rated:

[22] D. A. Voss, R. L. Terrel, F. Finn, and D. Hovey, *A Pavement Evaluation System for Maintenance Management*, paper presented at the Western Summer Meeting, Highway Research Board, August 1973.

TABLE D-1. CREDITS FOR DISTRESSES USED BY KING COUNTY[a]

Distress Type	Maximum Credit
Corrugations, shoving, and slippage	10
Flushing	5
Raveling	10
Rutting	10
Transverse cracking	5
Longitudinal cracking	5
Alligator cracking	10
Waves, sags, and humps	5
MAXIMUM CREDIT	60

[a]D. A. Voss, R. L. Terrel, F. Finn, and D. Hovey, *A Pavement Evaluation System for Maintenance Management*, paper presented at the Western Summer Meeting, Highway Research Board, August 1976.

TABLE D-2. CREDITS FOR DISTRESSES USED BY KING COUNTY[a]

Corrugations, shoving, and slippage	% Area	<1/4in.	1/4-3/4in.	>3/4in.
	0 - 10	10	5	0
	11 - 25	8	4	0
	>25	4	2	0
Flushing	% Area	Slight	Mod	Severe
	0 - 20	5	3	0
	21 - 35	4	2	0
	>35	2	1	0
Raveling	% Area	Slight	Mod	Severe
	0 - 25	10	5	0
	26 - 50	8	4	0
	>50	4	2	0
Rutting	% Area	0-1/2 in.	1/2-1 in.	>1 in.
	0 - 9	10	5	0
	10 - 30	8	4	0
	>30	4	2	0
Transverse cracking	No./Section	<1/4 in.	> 1/4 in.	Spalled
	0 - 4	5	3	0
	5 - 9	4	2	0
	≥ 10	2	1	0
Longitudinal cracking	Length/station	<1/4 in.	> 1/4 in.	Spalled
	0 - 20	5	3	0
	21 - 50	4	2	0
	>50	2	1	0
Alligator cracking	% Area	0-1/8 in.	1/8-1/4 in.	>1/4 in.
	0 - 5	10	5	0
	6 - 15	8	4	0
	16 - 30	4	2	0
	31 - 50	4	2	0
	>50	2	0	0
Waves, sags, and humps	% Area	Slight	Mod	Severe
	0 - 10	5	3	0
	11 - 50	4	2	0
	>50	2	1	0

[a]D. A. Voss, R. L. Terrell, F. Finn, and D. Hovey, *A Pavement Evaluation System for Maintenance Management*, paper presented at the Western Summer Meeting, Highway Research Board, August 1976.

1. 3/4-inch rutting over 15 percent of the area

2. an average of two spalled transverse cracks per 100-feet station

The credit for the rutting is 4 and the credit for the transverse cracks is 0. Since no other distresses are indicated, maximum credits are assigned for them, and the sum of the credits is 49.

The King County procedure is limited because credits are balanced based on distress types, as shown in Table D-1. Therefore, only one severity level and one density level can be considered for each distress in a given section. Also, the effects of individual distress types are added linearly; field surveys in this study showed that their effects combine nonlinearly.

MAINE DEPARTMENT OF TRANSPORTATION PROCEDURE

The procedure used by the Maine Department of Transportation (DOT)[23] is also a credit system. Weighting coefficients are assigned based on distress type alone, with the sum of all the coefficients being equal to 1.0. Within each distress type, a credit of 1, 2, 3, 4, or 5 is determined based on the subjective evaluation of distress condition (Table D-3). The pavement condition index is the sum of the product of the weighting factor and credit for each distress type. This can be expressed in an equation form as follows:

$$PCI = \sum_{i=1}^{n} w_i c$$

where n = number of distress types in the procedure

w_i = weight coefficient for each distress type (i)

c = credit as function of distress condition.

As an example, the PCI of the same pavement section used to illustrate the King County procedure (3/4 inch rutting over 15 percent of area and two spalled transverse cracks per station is calculated here:

$$PCI = (0.05 \times 5) + (0.14 \times 2) + (0.02 \times 5) + (.15 \times 5) + (.08 \times 5)$$

$$+ (.14 \times 2) + (.14 \times 5) + (.05 \times 5) + (.14 \times 5) + (.09 \times 3)$$

$$= 3.98 \text{ (out of a possible 5.0)}$$

[23]D. W. Rand, *Pavement Evaluation III*, Technical Paper (Maine Department of Transportation, Materials and Research Division, August 1973), pp 73-8.

TABLE D-3. CREDITS AND WEIGHTED COEFFICIENTS FOR DIFFERENT DISTRESSES USED BY MAINE DOT[a]

Defect type	Definitions for Severity Values 5	4	3	2	1	Weighted coef. for over-all rating	score - sev. value x coef.
Longitudinal crack	No cracks visible	Cracks not objectionable in appearance	Cracks visible - objectionable appearance	Objectionable appearance - may or may not be felt	Objectionable appearance - and ride	.05	
Random crack (transverse or shrinkage) or random	No cracks visible	Cracks visible	Cracks visible objectionable appearance	Objectionable appearance - may or may not be felt	Objectionable appearance and ride	.14	
Haircracks (fine cracks from placing of hot mix)	Apparently non-existent		Occasional amount		Considerable amount	.02	
Alligator cracking	No cracks visible	Slight cracking *visible*	Considerable cracks *visible*	Considerable Objectionable - *requires* maintenance	Pieces have or are able to come out	.15	
Temperature cracks (regular transverse)	No cracks		Cracks questionable as temperature cracks	Probably temperature cracks	Definetly recognizable and noticeable	.08	
Rutting	0 - .1" ave.	.1 - .25" ave.	.25 - .5" ave.	.5 -.75" ave.	> .75" ave.	.14	
Distortion	None	Slight distortion in a few areas	Slight distortion - ride not objectionable	Considerable and noticeable while driving	Serious deformation poor and un-pleasant riding	.14	
Washboard corrugations	None		Some noticeable to slight only	Washboard in "scal" only	Some noticeable and can be felt	.05	
Disintegration	No loss of aggregate (polished)	Small scale random loss or particles	Particular areas show surface scouring	General surface scouring	Severe loss of aggregate	.14	
General overall impression	______	(Purely	Subjective)	______	______	.09	

[a]D. H. Rand, *Pavement Evaluation III*, Technical Paper (Maine Department of Transportation, Materials and Research Division, August 1973), pp 73-8.

Although the procedure is simple, examination of Table D-3 reveals that severity and density levels are not well considered (e.g., rutting credits are assigned by severity only). Also, the effects of distresses are added linearly.

STATE OF WASHINGTON PROCEDURE

The State of Washington procedure developed by Leclerc and Marshall[24] is a deduct value system which is similar to the credit system except that negative numerical values are assigned to the distresses. The negative values are a function of the distress type, severity level, and density level. The deduct values are totaled for a given pavement section and then subtracted from a constant (100) to determine the pavement condition index. Table D-4 contains the deduct values for distress types used in the Washington procedure at different density and severity levels. Table D-5 is used to correct the total deduct values before subtraction from 100 to avoid negative values. The procedure can be expressed in equation form:

$$PCI^* = 100 - \sum_{i=1}^{n} a(T_i, S, D)$$

n = number of distress types identified in the pavement

$a(T_i, S, D)$ = deduct value for each distress type (T_i) as function of severity (S) and density (D).

*Riding quality is determined separately, and a combined index is calculated.

Evaluating the pavement section used in the King County and Maine procedure examples gives a pavement condition index of 85 out of 100: $PCI = 100 - \Sigma(5 + 10)$.

The Washington method is also limited by the fact that deduct values cannot be totaled for different severity levels within a given distress type, so that only one severity of a distress can be rated for a given section. As in the other methods, the effects of different distress types are added linearly.

OTHER METHODS

Methods similar to those presented here have been developed. They include the Saskatchewan Department of Highways and Transportation

[24] R. V. LeClerc and T. R. Marshall, "A Pavement Condition Rating System and Its Use," *AAPT Proceedings of Symposium on Pavement Evaluation*, 1969.

TABLE D-4. DEDUCT VALUES IN WASHINGTON METHOD[a]

	% of road length	0 - 25	25 - 50	50+
Rutting	0 - 1/2 in. ave. depth	0	2	5
	1/2 - 1 in. ave. depth	5	7	10
	1 - 4 in. ave. depth	10	12	15
	2 - 4in. ave. depth	15	20	25
	4 in. ave. depth	30	35	40
	% pavement area	hairline	spalling	spalling+ pumping
Alligator Cracking	0 - 24	2	5	10
	24 - 44	5	10	15
	50 - 74	10	15	20
	75	15	20	25
	% pavement area	slight	mod	severe
Corrugation	0 - 15	5	8	10
	16 - 35	10	12	15
	35+	15	18	20
	lineal ft/sta.	<1/4 in.	>1/4 in.	spalled
Longitudinal Cracking	10 - 99	5	10	15
	100 - 99	10	15	20
	200+	15	20	25
	# cracks	<1/4 in.	>1/4 in.	spalled
Transverse Cracking	0 - 4 per station	3	5	10
	5 - 9 per station	4	7	12
	10+ per station	5	10	15
	% pavement area	0 - 1/2 in.	1/2 - 1 in.	1 in. +
Patching	0 - 5	2	5	7
	6 - 25	5	7	10
	25 +	7	10	15
	in. change/10 ft.	0 - 25	25 - 75	75+
Waves Sags & Humps	1 - 2	10	15	20
	2 - 4	20	25	30
	4 +	30	35	40

[a] R. V. Leclerc and T. R. Marshall, "A Pavement Condition Rating System and Its Use," *AAPT Proceedings of Symposium on Pavement Evaluation*, 1969.

procedure developed by Winnitoy; the Minnesota Department of Highways method developed by Hughes; and the D. E. Currier - SURF Evaluation developed by Forbes.

TABLE D-5. CORRECTION OF TOTAL DEDUCT VALUES IN WASHINGTON METHOD[a]

Total Deducts	Use This for Subtraction From 100
up to 90	as calculated
91 - 94	91
95 - 105	93
106 - 115	95
116 - 125	97
126 - 140	98
140+	

[a]R. V. Leclerc and T. R. Marshall, "A Pavement Condition Rating System and Its Use," *AAPT Proceedings of Symposium on Pavement Evaluation*, 1969.